DOCUMENT RESUME

ED 168 826 SE 026 892

AUTHOR Shapley, Willis H.; Phillips, Don I.

TITLE R&D in the Federal Budget: FY 1979, R&D, Industry, and the Economy. Research & Development, AAAS Report III.

INSTITUTION American Association for the Advancement of Science, Washington, D.C.

REPORT NO AAAS-Pub-78-8

PUB DATE 78

NOTE 130p.; Some small type may be marginally legible

AVAILABLE FROM American Association for the Advancement of Science, 1515 Massachusetts Ave., N.W., Washington, D.C. 20005 ($6.00)

EDRS PRICE MF01/PC06 Plus Postage.

DESCRIPTORS *Budgets; Federal Aid; *Federal Government; *Financial Support; *Program Budgeting; Research; Research Opportunities; Science Education; Sciences; *Scientific Research

ABSTRACT

The federal government's budgeting process for allocating resources to research and development (R&D) is described. The report includes: (1) a review of the FY 1979 R&D budget; (2) a statistical overview of the budget and a critique of the administration's policies on R&D; (3) a general picture of R&D in industry; and (4) a discussion of some of the questions involved in understanding the impact of R&D on the economy. (BB)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

ED168826

RESEARCH & DEVELOPMENT AAAS REPORT III

R&D in the Federal Budget: FY 1979

R&D, Industry, & the Economy

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Grayce A. Finger

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) AND USERS OF THE ERIC SYSTEM."

Willis H. Shapley
Don I. Phillips

American Association for the Advancement of Science

SE 026 892

RESEARCH & DEVELOPMENT AAAS REPORT III

R&D in the Federal Budget: FY 1979
R&D, Industry, and the Economy

A Report
prepared for the Executive Officer
and the AAAS Committee on
Science, Engineering, and Public Policy

Willis H. Shapley
Don I. Phillips

American Association for the Advancement of Science
Washington, D.C.

The AAAS Board of Directors, in accordance with Association policy, has approved publication of this study as a contribution to the understanding of an important process. The interpretations and conclusions are those of the authors and do not purport to represent the views of the Board or the Council of the Association.

Printed in the United States of America

Library of Congress Catalog Number 78-58331
International Standard Book Number 0-87168-236-2
AAAS Publication Number 78-8

Copyright © 1978 by the
American Association for the Advancement of Science
1515 Massachusetts Avenue, NW, Washington, D.C. 20005

Contents

List of Tables v

Foreword William D. Carey ix

Acknowledgments xi

Overview of the Report xiii

Part I R&D in the Federal Budget

Chapter 1. Carter's First Two Budgets 3

A Carter's First Year 3
B FY 1978 Budget Outcome 6
C The FY 1979 Budget 8

Chapter 2. R&D in the FY 1979 Budget 13

A Statistical Overview 13
B R&D Policies in the FY 1979 Budget 16
1 Evolution, 16
2 The Policies, 17
3 Comments and Critique, 19
C R&D Budget Highlights 21
1 Basic Research, 21
2 R&D at Colleges and Universities, 23
3 Climate R&D, 25
4 Earthquake Research, 25
5 Energy R&D, 25
6 Environmental R&D, 27
7 Competitive Grants for Agriculture R&D, 27
8 Health Research, 29

5

9 R&D in Education, 29
10 Social Science R&D, 31

D Agency R&D Trends 32

1 Agency Totals, 32
2 R&D in the Department of Defense, 33
3 R&D in the Department of Energy, 36
4 R&D in the National Aeronautics and Space Administration, 37
5 R&D in the Department of Health, Education, and Welfare, 38
6 R&D in the National Science Foundation, 40
7 R&D in the Environmental Protection Agency, 41
8 R&D in the Department of Agriculture, 43
9 R&D in the Department of Commerce, 43
10 R&D in the Department of Transportation, 44
11 R&D in the Department of the Interior, 45
12 R&D in the Agency for International Development, 46

Part II R&D, Industry, and the Economy

Introduction 51

Chapter 3. R&D in Industry 53

A Profile of Industry R&D 55
B Recent Trends 59
C Future Outlook 64

Chapter 4. R&D and the Economy 72

A How Does R&D Help the Economy? 72
B What Do the Studies Show? 77
C R&D and Current Economic Problems 79

Chapter 5. The Bottom Line Questions 82

Appendixes

A General R&D Statistics – Supplementary Tables 87
B Agency R&D Budget Tables 93
C R&D in Industry – Supplementary Tables 107

List of References

A General 113
B Agency Budgets 114
C R&D, Industry, and the Economy 115

About the Authors 119

List of Tables

Table 1	FY 1978 Budgets for R&D: Total Presidential Recommendations and Principal Identifiable Congressional Changes	7
Table 2a	Total Budget, Federal R&D, and GNP in Current Dollars	10
Table 2b	Total Budget and Federal R&D in Constant 1972 Dollars	11
Table 3	Total Federal Funding for R&D	14
Table 4	Major Components of Federal Funding for Conduct of R&D	15
Table 5	Conduct of R&D by Character of Work	15
Table 6	Conduct of Basic Research by Agency in Current and Constant 1972 Dollars	22
Table 7	Support for Conduct of R&D at Colleges and Universities	23
Table 8	U.S. Climate Program: FY 1979	24
Table 9	Nuclear and Non-Nuclear R&D in the Department of Energy	26
Table 10	Environmental R&D in the FY 1979 Budget	28
Table 11	R&D in the Cooperative State Research Service, Department of Agriculture	28
Table 12	Estimated Federal Support for Social Science R&D	30
Table 13	Research and Development in the FY 1979 Budget by Agency	34
Table 14	Conduct of R&D in the Department of Health, Education, and Welfare	39
Table 15	Conduct of R&D in the Department of Agriculture	42

Table 16	Conduct of R&D in the Department of Commerce	45
Table 17	Conduct of R&D in the Department of Transportation	45
Table 18	Conduct of R&D in the Department of the Interior	46
Table 19	R&D in the AID Development Support Bureau	46
Table 20	Industry in the National Pattern of R&D, 1978	56
Table 21	Total National and Business Enterprise R&D in Selected OECD Countries, 1975	57
Table 22	R&D Performed by Industry by Source of Funds, 1967–1978	60
Table 23	R&D Funded by Industry by Performers of R&D, 1967–1978	60
Table 24	Character of R&D Performed by Industry, 1967–1978	62
Table 25	Character of R&D Funded by Industry, 1967–1978	62
Table A-1	Basic Research by Field of Science: Data Classified as in FY 1978 Budget	89
Table A-2	Applied Research by Field of Science: Data Classified as in FY 1978 Budget	90
Table A-3	National Funds for R&D by Source	91
Table A-4	National Funds for R&D by Performer	92
Table B-1	Department of Defense Research, Development, Test, and Evaluation (RDT&E)	94
Table B-2	R&D in the Department of Energy	96
Table B-3	National Aeronautics and Space Administration Budget Summary	99
Table B-4	National Institutes of Health	100
Table B-5	Alcohol, Drug Abuse, and Mental Health Administration	101
Table B-6	National Science Foundation	102
Table B-7	Environmental Protection Agency: "Research and Development" Appropriation	104
Table B-8	EPA: Office of Research and Development Budget by Media	104
Table B-9	EPA: Office of Research and Development Budget by Program Area	105
Table C-1	Industry Spending for R&D by SIC Groupings: 1975 and 1976	108
Table C-2	Industry Spending for R&D by *Business Week* Groupings: 1975 and 1976	110

Table C-3 Applied Research and Development Performed by Industry, by Product Field and Source of Funds: 1976 111

Table C-4 Basic Research Performed by Industry, by Field of Science 112

General Notes

1. Due to rounding in the tables, detail may not add to the totals, and percent changes may not correspond exactly to the differences shown.
2. The conversions to constant 1972 dollars have been made by the authors using the annual GNP implicit price deflators of the Department of Commerce, Bureau of Economic Analysis, and the projected deflators for 1978 and 1979 contained in the President's FY 1979 budget.

Foreword

Three years ago, AAAS set out to test its ability to produce an annual analytic report on research and development in the federal budget. This idea had been simmering in the Committee on Science and Public Policy for some time, and was premised on the view that the budgeting process was the key to the government's decision-making and priority-setting behavior for research and development. If the budgeting process could be demystified and tracked over time, the quality and consequences of R&D budget decisions could be examined and alternatives put forward by interested members of the scientific and technical communities. As a window on the anatomy of science policy, the budget process had no peer.

On this basis, we proceeded in an experimental frame of mind to see what could be done with the project. We were fortunate in persuading Willis Shapley, a veteran of the R&D budgetary wars in both the Bureau of the Budget and NASA, to join us and tackle the job. The results have been rewarding. Because the AAAS report has sought to be fair as well as objective and not self-serving, AAAS has been able to secure excellent cooperation from the administration, the Congress, and the federal agencies in supplying information and data needed to construct the analyses with dispatch. The report is still prepared under Mr. Shapley's direction, with the assistance for the past 2 years of Don Phillips, and it has become the mainstay of AAAS's work program in the field of science policy.

The report remains in an experimental mode. Each year, a different set of institutional problems is being addressed in the context of the federal budget for research and development. In the first year, principal emphasis was given to the budget process and decision-making approaches to funding R&D. The following year, special attention was given to the environment of congressional review and action on budgets for R&D. The current report builds on the two previous versions and begins to explore the interrelationships between government and private industry in supporting R&D, and the indicative reflex of R&D on the nation's economic performance.

Thus the report, and the mid-year AAAS Colloquium on Science Policy, attempts to make somewhat more coherent the usually floundering debates on the nature and shortcomings of policy management for research and development. This is a role that we think an important one for AAAS, but until now it has been difficult to find a useful handle. If the annual report continues to earn the respect of its various audiences, ranging from the White House to Congress, private industry, academia, and state and local governments, the possibilities will be somewhat better for reducing drift and uncertainty and reaching a substantial consensus on acceptable terms for allocating resources to research and development.

WILLIAM D. CAREY
Executive Officer
American Association for the Advancement of Science

Acknowledgments

I should like to express my appreciation to the AAAS Committee on Science, Engineering, and Public Policy for its continued interest in the AAAS reports on R&D budgets and policies, of which this is the third. The suggestions of the Committee were helpful in planning the report. The Committee should bear no responsibility for the content of the report, however; Committee review is made impractical by the tight schedule between the release of the budget and the deadlines required for publication prior to the AAAS colloquium.

The assistance of the many people in federal agencies, industry, and professional societies who contributed information or advice is gratefully acknowledged. Special thanks are due officials of the Office of Management and Budget and the National Science Foundation for their cooperation in making available budget statistics and other essential information. Don I. Phillips of the AAAS performed the detailed budget analyses again this year and provided valuable assistance on the entire report. Mr. William D. Carey, Executive Officer of the AAAS and Dr. Thomas Ratchford, Head of the Office of Public Sector Programs, provided wise and helpful guidance. Kathryn Wolff and Anne Holdsworth and their associates in the AAAS publications office again met with flying colors the challenges of producing the report in a highly compressed time schedule. Patricia Curlin and the support staff in the Office of Public Sector Programs did yeoman service in assembling needed materials, typing, and proofreading. The preparation of the report was supported in part by the Alfred P. Sloan Foundation, whose continued interest in AAAS science and technology policy activities is again gratefully acknowledged. Full responsibility for the opinions, shortcomings, and errors in the report is mine.

WILLIS H. SHAPLEY

Washington, D.C.
April 1978

Committee on Science, Engineering, and Public Policy
(1977–1978)

Melvin Kranzberg, *Chairman*
Callaway Professor of the History of Technology
Georgia Institute of Technology

Edward E. David, Jr., President
Exxon Research and
Engineering Company

Thane Gustafson
Assistant Professor of
Government
JFK School of Government
Harvard University

Phyllis Kahn, Member
Minnesota State Legislature

Sanford A. Lakoff
Chairman, Department of
Political Science
University of California
San Diego

*John M. Logsdon, *Past Chairman*
Director, Graduate Program
in Science, Technology
and Public Policy
George Washington University

*T. Dixon Long
Provost, Western Reserve College
Case Western Reserve University

*Jessica Tuchman Matthews
Global Issues Office
National Security Council

Robert P. Morgan
Chairman, Department of Tech-
nology, and Human Affairs
Washington University

Dorothy Nelkin
Program on Science, Technology
and Society
Cornell University

Richard R. Nelson
Department of Economics
Yale University

Rodney Nichols, Vice President
The Rockefeller University

Albert H. Rosenthal
Director, Program for Advanced
Study in Public Science
Policy and Administration
University of New Mexico

*Harvey Sapolsky
Professor of Political Science
Massachusetts Institute of
Technology

Benjamin S. P. Shen
Chairman, Astronomy and
Astrophysics
The University of Pennsylvania

Jon Veigel
Director, Research and
Development
Energy Resources Conservation
and Development Commission
State of California

Irvin L. White
Science and Public Policy
Program
University of Oklahoma

Philip Yeager, Counsel
Committee on Science and
Technology
Subcommittee on Science,
Research and Technology
U.S. House of Representatives

* Terms expired February 17, 1978.

Overview of the Report

This is the third in what has become a series of annual reports on research and development budgets and policies prepared for the AAAS in its Office of Public Sector Programs. Like its predecessors, which we shall refer to as *AAAS–I* and *AAAS–II*,[1] respectively, *Research & Development: AAAS Report III* is addressed to the scientific and technical community and to the broader community, in government, industry, and the public at large, that is concerned with R&D programs and policies.

AAAS–I presented an analysis of R&D in the federal budget for FY 1977 and laid a foundation for the succeeding volumes by giving a fairly detailed exposition of the federal budget process, the handling of R&D in the budget, the problems of interpreting budget statistics, and the principal R&D budget issues of continuing concern. *AAAS–II* reviewed R&D in the federal budget for FY 1978 and addressed as special topics a suggested conceptual basis for R&D budget decisions and the congressional role in R&D budgeting.

Each of the first two reports served as the basis for an AAAS-sponsored colloquium on R&D policy in Washington, D.C., at which senior officials of the Executive Branch, members of Congress, and other government officials met with concerned individuals from industry, universities, and the scientific, technical, and public-policy communities for frank interchanges on problems and issues of mutual concern.[2] The responses to the reports and the colloquia have been generally quite favorable; it appears that they have succeeded in achieving a heightened awareness of R&D problems on the part of responsible government officials and a more balanced understanding of

[1] Citations to these reports are found under Shapley et al. in the List of References. Citations to all publications referred to in this book will be found in one of three categories in the List of References: The "General" references include publications pertaining to R&D in the federal budget; the section headed "Agency Budgets" includes congressional budget justifications of individual agencies; and "R&D, Industry, and the Economy" contains documents related to Part II of the report collected in two subcategories, "R&D in Industry" and "R&D and the Economy."

[2] Citations to the proceedings of these colloquia are found under Blanpied et al. and Phillips et al. in the "General" section of the List of References.

the government's problems with respect to R&D on the part of the scientific and technical community.

This year, the scope of the report, and of the colloquium to be held in June 1978, has been expanded. The report continues, in Part I, the series of annual analyses of R&D policies and programs in the President's budget. Part II goes outside the confines of the federal budget to examine funding and problems of R&D in industry and the impact of R&D, government and private, on the economy. The broader scope is intended both to recognize the vital importance of industry R&D and of R&D to the economy and to give a better reflection of the full range of AAAS interest in R&D and science and technology policy.

Part I of the report, like its counterparts in previous years, has a dual purpose. It analyzes R&D in the President's FY 1979 budget to show what is in the budget for R&D, what the trends are, how the budget process is working, and perhaps more importantly, to identify, illuminate, and assess the basic issues of R&D policy. Chapter 1 sets the context with an account of how President Carter's R&D recommendations for FY 1978 fared in Congress and a general review of the FY 1979 budget he submitted to Congress in January 1978. Chapter 2 proceeds to a statistical overview of R&D in the FY 1979 budget and a discussion and critique of the administration's policies on R&D. Next, there are discussions of ten topical highlights of R&D in the FY 1979 budget, followed by brief analyses of overall R&D budget trends and of trends and programs in about a dozen of the leading agencies engaged in R&D. Issues that merit further consideration, at the AAAS colloquium and by all concerned, are identified in the policy critique and throughout the discussions.

In Part II, the first chapter gives a general picture of R&D in industry, its nature and content, recent trends, and future outlook, and identifies some problems that deserve further consideration. The second chapter discusses some of the complex questions involved in understanding the impact of R&D on the economy and the implications for policy in government and in industry, again identifying problems that appear to deserve additional and expert attention. The final chapter attempts to distill from the earlier discussions the "bottom line" operative questions which it appears will have to be dealt with, by decision or default, in the period immediately ahead. The aim in Part II has not been a definitive discussion of R&D in industry or of the impact of R&D on the economy, but to provide a sharper focus for constructive discussion, at the AAAS colloquium and elsewhere, of an exceedingly complex set of interrelated and vital issues.

The role of the AAAS in this report is not one of special pleading for R&D as such, for particular programs on R&D, or for any specific point of view on controversial issues. It is, rather, to promote a wider and clearer understanding of issues that are of great interest and serious concern from many different, sometimes conflicting standpoints, all of which have a legitimate and welcome place in the AAAS community.

I

R&D in the Federal Budget FY 1979

Chapter 1

Carter's First Two Budgets

To provide a setting for examining R&D in President Carter's FY 1979 budget, we will review briefly his first year as it relates to R&D and the budget process, see what Congress did to R&D in the amended FY 1978 budget, and take a look at the overall shape of the Carter budget for FY 1979.

A. Carter's First Year

President Jimmy Carter's first year in office was devoted mainly to getting his administration in place, beginning to translate his campaign outlook into concrete programs, learning to work with Congress and in the international arena, and dealing with the myriad of day-to-day matters with which a President is always beset. The new administration had its hands full; its main preoccupations included fiscal stimulation of a wavering economy, reestablishment of presidential authority to reorganize the Executive Branch, establishment of the Department of Energy, rescue of the top priority energy bill that bogged down in Congress, decisions to terminate the Clinch River reactor and B-1 bomber, responding to the ups-and-downs of Mideast peace negotiations, weathering the controversies leading to the resignation of Budget Director Bert Lance, and beginning the struggle for Senate ratification of the Panama Canal treaties.

R&D was not a factor in these front-line issues, except in the Clinch River and B-1 matters. The President's decision to propose cancellation of the Clinch River breeder reactor project reflected a significant reorientation in the nuclear energy R&D program, although the administration's foreign policy concerns with limiting the availability of nuclear weapons materials and the opposition of regional interests that stood to lose if the project were terminated also became major issues. In the B-1 case, the immediate issues were the need and the high cost of production

and development, not completion of R&D on the B-1 itself, and the cancellation "package" did include increased R&D on cruise missiles and studies of possible adaptations of F-111's as a partial substitute for the B-1.

As recounted in AAAS-II, President Carter's amendments to President Ford's FY 1978 budget in February 1977 did not make major policy changes in R&D. There was a cut of $260 million in military R&D to stretch out certain projects, but this was offset a few months later by supplemental estimates of almost the same amount for the increased R&D in the B-1 cancellation package. Some changes were proposed in energy R&D to effect a policy placing more emphasis on conservation and less on some long-term energy R&D, including Clinch River. The other Carter budget amendments affecting R&D were minor; in R&D, as in most other areas, the new administration quite reasonably decided not to make major changes until the FY 1979 budget.

Within the Executive Branch things moved more slowly than many had expected. The new administration took a long time to select key officials in many agencies, and the Senate took its time in confirming them. Some cabinet departments got their new leadership in place fairly rapidly—Defense, State, and the Department of Health, Education and Welfare (HEW), for example—but many of the principal scientific and technical agencies were among those kept in suspense until late spring, early summer or even longer, before their new heads were named and confirmed: NSF, NASA, National Oceanic and Atmospheric Administration (NOAA), and the National Bureau of Standards (NBS) had this experience. Part of the delay was doubtless caused by President Carter's reasonable desire first to resolve questions on the future of the Office of Science and Technology Policy (OSTP) and then to have its head help select the rest of the administration's scientific and technical team.

The conception of the reestablished Office of Science and Technology Policy, as set forth in law by its congressional sponsors during the final year of the Ford administration, collided headlong with President Carter's views on how the White House and Executive Office should function. The President was committed to a substantial reduction in Executive Office staff; the wide array of functions specified in the OSTP law would have required an increase. The President and his staff wanted to avoid giving special interests a foothold inside the gates of the Executive Office; OSTP was regarded by many, including perhaps the bulk of the scientific and technical community, as a special pleader for science and technology at the President's ear. After apparently giving serious consideration to outright abolition of OSTP, the President finally agreed with those who saw a genuine need for a science adviser in the White House, or who at least felt it imprudent to have a confrontation on this point with Congress or the scientific community. He decided to preserve a small OSTP, limited to about a dozen professionals, to abolish and redefine some of the more cumbersome functions and machinery specified in the OSTP act, and to appoint Dr.

Frank Press of MIT to serve as his science adviser and head of OSTP. Dr. Press accepted the challenge and the limitations. Keeping a low profile, he soon found, as we shall see, an effective role among the policy-makers in the Executive Office.

Meanwhile the principal protagonist on budget matters in the Executive Office, the Office of Management and Budget (OMB), was getting off to a strong start, even though its titular leader, Bert Lance, seems to have left the management of the budget process mostly to his assistants, concentrating instead on economic policy matters and later on the investigations into his own affairs, until his resignation. As expected, zero-base budgeting (ZBB) was duly proclaimed by OMB; a few dissidents who protested that it couldn't be done were quickly straightened out. OMB organized a series of pre-budget, presidential meetings in late spring, at which the leadership of each major agency had the unusual opportunity of discussing his program plans and recommendations for administration policy; specific budget figures were generally not discussed, but the OMB troops were present in force and the probable issues received at least a preliminary airing. As the year progressed, preparations for the FY 1979 budget moved along the traditional path. Planning figures ("ceilings") were given the major agencies; the agencies prepared their estimates, generally in the new ZBB format; and OMB, the President, and his administration began to face the difficult task of deciding what the first true Carter budget would be like.

Meanwhile, the Congress was adjusting to new leadership in both House and Senate and to the changed line-up in which the administration and Congress were controlled by the same party. The new congressional budget system functioned well enough for another passing grade, but lost much of its earlier steam. Procedures that had a special appeal as a means for a Democratic Congress to work its will on a Republican President began to seem somewhat hollow and mechanical when applied to a President of their own party. Thus, only a few months after setting a "final" ceiling on FY 1977 expenditures and a "final" floor on FY 1977 receipts, the Democratic Congress obediently raised the ceiling and lowered the floor to accommodate the economic recovery measures recommended by their new President.

The forms, at least, of the rest of the congressional budget process were pretty well followed, and the expedited schedule of congressional consideration of authorization and appropriation bills—a major benefit of the new process—was generally maintained. But some of the overly detailed procedural prescriptions in the 1974 Budget Act began to present problems. For example, OMB, the Congressional Budget Office, and congressional budget committees agreed to dispense with the "current services" estimates which the law requires OMB to submit on November 15 as a baseline for advance economic and budget planning in the Congress. This had proved an ill-timed exercise since OMB's estimates are necessarily in a state of flux until all the decisions on the

next year's budget are made in late December or early January; the new agreement more sensibly provides that "current services" estimates consistent with the President's budget recommendations will be included in the January budget documents.

The detailed procedures required under the Impoundment Control title of the 1974 Budget Act, designed to thwart President Nixon's thwarting of Congress, also caused some embarassment. Pro-B-1 forces in the House, defeated on a direct vote, found that the fine print enabled a small number of them to block the cancellation of the program simply by having the House Appropriations Committee, where they had a majority, refuse to act on the necessary "recission" measure submitted by the President. This unseemly situation was resolved by old-fashioned tough talk by the leadership, and the country was instead treated to the only slightly more edifying spectacle of a long cat-and-mouse vote-scheduling game by both supporters and opponents which delayed final congressional action approving the President's June 1977 decision to February 1978.

B. FY 1978 Budget Outcome

While larger matters like the energy bill, the B-1 and Clinch River disputes, and Bert Lance held the spotlight, Congress labored through its annual review of agency budgets. Let us look briefly at what the congressional process did to R&D in the 1978 budget as amended by President Carter. In total, there isn't a good answer, but we can identify the major cuts and additions.

As discussed in detail in AAAS-1 and as we will see again when we come to R&D in the FY 1979 budget, the totals for R&D are based on statistics put together each year by the Office of Management and Budget in "Special Analysis P," published with the President's budget. The R&D amounts for each agency are generally estimates, often without accounting support, of the portion of each budget item that was considered as falling within the standard NSF definitions of R&D. Congressional actions range all the way from general cuts in broad appropriation accounts to detailed adjustments in specific projects. There is no official scorekeeping on R&D; the best one can do is to scan the congressional appropriations reports and pick out the actions that specifically or presumably affected the amounts for R&D. By the time the next annual OMB estimates update the R&D figures, they will have been subjected to further program adjustments by the agencies and to statistical changes in the way the estimates are put together from year to year.

Table 1 shows the picture for R&D in the FY 1978 budget. Identifiable congressional actions had the net effect of a $413 million, or 1.5 percent, reduction in the budget requests. The biggest dollar

changes were the $732 million cut in Defense and the $220 million increase at the National Institutes of Health (NIH). In the case of Defense, the total reduction is made up of over a hundred adjustments to individual projects, not reflecting significant policy changes but providing a testimonial to the degree of detail congressional control reaches. In the case of NIH, the large increase was the expected

Table 1. FY 1978 Budgets for R&D: Total Presidential Recommendations and Principal Identifiable Congressional Changes (Budget Authority in millions).

	Amount	Percent Change
Total Research and Development		
Original budget (President Ford)	$28,048	
Budget amendments, Feb. 22, 1977	−321	−1.1%
Revised budget (President Carter)	$27,727	
Supplemental estimates[1]	+389	+1.4%
TOTAL considered by Congress	$28,116	
Principal identifiable changes by Congress, net (see below)	−413	−1.5%
All other changes, net[2]	−325	−1.2%
TOTAL FY 1978 budget authority for R&D, FY 1979 budget	$27,378	
Congressional Changes (principal identifiable R&D items only)		
Department of Defense	−$732	−6.1%
Energy Research & Development Administration	+99	+2.2%
National Aeronautics & Space Administration	−17	−0.4%
National Science Foundation	−20	−2.5%
National Institutes of Health	+220	+9.2%
Alcohol, Drug Abuse, and Mental Health Administration	+13	+8.4%
National Institute of Education	−19	−17.4%
Environmental Protection Agency	+19	+6.4%
Department of Agriculture	+19	+3.3%
Department of Commerce	+11	+1.6%
Department of Housing & Urban Development	−8	−13.3%
Veterans Administration	−1	−0.9%
Nuclear Regulatory Commission	−2	−1.4%
U.S. Geological Survey	+5	+1.4%
NET TOTAL, above changes by Congress	−$413	−1.6%

Source: AAAS II and congressional appropriations reports, 95th Cong., 2d sess.

[1] Identifiable R&D items submitted for first FY 1978 supplemental appropriation.

[2] Includes only changes by Congress, agency adjustments and reestimates, and OMB and agency redefinitions.

outcome of the annual charade in which Congress increases the unrealistically low figures OMB has put in the President's budget because Congress is sure to increase them.

In energy, Congress tempered somewhat its tendency of recent years to demonstrate its resolve to do something about the energy crisis by pouring more and more money into energy R&D. The build-up of unused balances of the large increases previously pumped into fossil energy R&D led to a $50 million general cut. But the same situation in solar energy did not deter Congress from adding about $50 million above the budget. Congress also insisted on restoring funds to force continuation of the Clinch River breeder reactor project in spite of both the President's desire to terminate the project and his veto of the legislation authorizing this appropriation.

The National Science Foundation (NSF) got a $15 million cut in the former RANN program of research applied to national needs, but the general increase in basic research support recommended as a policy matter in the Ford budget was generally approved, as were most of basic research increases in the Department of Defense (DOD). One major NASA program had a close call: the House Appropriations Committee balked at agreeing to the Jupiter orbiter and probe project, but in an unusual display of political support for a pure science program, the full House of Representatives overrode the committee and approved the project. Other programs did not fare so well. The proposed $30 million program of competitive grants for basic agriculture research was cut in half, although other Department of Agriculture R&D activities were increased. The National Institute of Education (NIE) and the Department of Housing and Urban Development (HUD) ran into congressional skepticism and got substantial percentage cuts in their R&D budget requests.

In summary, it is fair to say that Congress generally supported the Ford-Carter budget recommendations for R&D, with a few changes around the edges. Such problems as R&D has in Congress stem from differences in the merits of particular items as perceived by their proponents on one side and by the committees or congressional staff responsible for detailed review on the other. A Congress that appropriates over $27 billion for R&D can't be said to be unsympathetic!

C. The FY 1979 Budget

The FY 1979 budget was bound to be the first comprehensive test of the Carter administration. Decisions now had to be faced that could reasonably be deferred for further study when the new administration hastily reviewed and proposed a few amendments to the FY 1978 budget just after taking office. Hopes and expectations of the many different interest groups that supported Candidate Carter would now have to be sustained or disappointed by President Carter. The budget would

unavoidably give liberals and conservatives some signals on where their President stood.

It was not an easy budget to put together. There was the campaign promise to bring the budget into balance by FY 1981—the final budget of the first term—and the need to demonstrate fiscal responsibility to the business community. At the same time, a shaky economic recovery clearly dictated a large deficit and tax cuts, although advisers differed on the amounts and timing. The energy bill, affecting both revenues and expenditures, was bogged down. Key initiatives—welfare reform, urban redevelopment, education—kept coming in with price tags that were too high. Important but politically unpopular objectives had to be weighed against needs for congressional support.

The budget that was finally unveiled in the State of the Union and budget messages managed to have both a conservative and liberal flavor. Fiscal conservatives could take heart from the President's frank acknowledgment that the federal government should not be looked to to solve all the nation's ills, from the facts that the overall increase in spending was only about 2 percent above the rate of inflation and the share of the GNP taken by the federal government was reduced, and from the anguished screams on the liberal side that the Carter budget had not treated them much better than the Republicans would have. The liberal wing could take satisfaction in the emphasis on a fiscal stimulus to strengthen the economy, in the sizable increases for most areas of national needs over the amounts projected a year ago by the outgoing Ford administration but with a lesser increase for national defense, and in the renewed commitments to meeting essential human needs and protecting the environment. Optimistic economic projections managed to hold open the possibility of a balanced budget in FY 1981. New 3-year budgeting procedures were promised starting next year. For the scientific and technical community there were the pleasant surprises of the strong endorsements of science and technology in the State of the Union message and, for the second year in a row, in the budget message. As we will see in the next chapter, President Carter, like President Ford a year earlier, went out of his way to include a statement on the importance of increasing support of basic research, one of only about a half dozen topics singled out for mention.

Table 2a shows the overall structure of the budget, identifying separately the portion that goes to R&D, and the way each major segment has grown since 1967. Total outlays have more than tripled since 1967 and the FY 1979 budget pushes them over the half-trillion mark. Over half the total goes for payments to individuals (social security, medicare, etc.) and grants to states and localities (welfare, revenue sharing, highways, etc.). National defense takes another big bite, as does the growing interest bill. R&D is only 5.7 percent of total outlays, but national defense R&D is almost 12 percent of total national defense, and all other R&D is over 20 percent of the total for general, nondefense operations of the government—excluding payments to

Table 2a. Total Budget, Federal R&D, and GNP in Current Dollars (in billions).

	FY 1967 Actual	FY 1972 Actual	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget
Outlays					
R&D Outlays					
National Defense	$ 8.3[1]	$ 9.0[1]	$ 11.4	$ 12.7	$ 13.8
All Other R&D	8.6	7.7	11.8	13.5	14.6
TOTAL, R&D Outlays	$ 16.9	$ 16.7	$ 23.2	$ 26.2	$ 28.4
Other Outlays					
National Defense (excluding R&D)	$ 59.9	$ 67.6	$ 86.1	$ 94.9	$ 104.0
Payments to Individuals and Grants to States and Localities[2]	50.2	106.1	226.9	251.9	272.1
Net Interest	10.3	15.5	30.0	35.2	39.9
Other Nondefense (excluding R&D)	20.9	26.1	35.6	53.9	55.6
TOTAL Outlays	$158.3	$ 232.0	$ 401.9	$ 462.2	$ 500.2
Receipts (total)	$149.6	$ 208.6	$ 356.9	$ 400.4	$ 439.6
Deficit	−$ 8.7	−$ 23.4	−$ 45.0	−$ 61.8	−$ 60.6
TOTAL **GNP**	$774.4	$1,110.5	$1,838.0	$2,043.2	$2,274.6
R&D Outlays					
As Percent of Total Outlays	10.7%	7.2%	5.8%	5.7%	5.7%
As Percent of GNP	2.2%	1.5%	1.3%	1.3%	1.2%

Source: Office of Management and Budget, FY 1979 and FY 1977 Budgets; "Special Analysis P," FY 1979 Budget; *Federal Funds*, Volume XXV, NSF.

[1] Authors' estimates based on above sources.

[2] Cooperative State Research Service, Department of Agriculture, excluded here and included in R&D Outlays.

Table 2b. Total Budget and Federal R&D in Constant 1972 Dollars (in billions).

	FY 1967 Actual	FY 1972 Actual	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget
Outlays					
R&D Outlays					
National Defense	$ 10.5	$ 9.0	$ 8.1	$ 8.5	$ 8.7
All Other R&D	10.9	7.7	8.3	9.0	9.2
TOTAL, R&D Outlays	$ 21.4	$ 16.7	$ 16.4	$ 17.5	$ 17.8
Other Outlays					
National Defense (excluding R&D)	$ 75.8	$ 67.6	$ 60.9	$ 63.3	$ 65.3
Payments to Individuals and Grants to States and Localities	63.5	106.1	160.6	168.0	171.0
Net Interest	13.0	15.5	21.2	25.5	25.1
Other Nondefense (excluding R&D)	26.4	26.1	25.2	36.0	34.9
TOTAL Outlays	$200.3	$232.0	$284.4	$308.3	$314.3

Source: Data in Table 2a converted to constant 1972 dollars by authors.

individuals, grants, and interest. Even though federal R&D spending as a percent of total outlays and as a percent of the GNP has declined some 45 percent since 1967, it has become a fiscally significant fraction of the relatively controllable part of the federal budget.

A more realistic picture of the trends in the total budget is given in Table 2b, where we have converted the figures in Table 2a to "constant 1972" dollars by applying the overall GNP implicit price deflator (as reported by the Department of Commerce for past years and projected in the President's budget for the future). While the total FY 1979 budget is still more than half again as high as FY 1967, the indicated increase over FY 1978 is less than 2 percent. On this constant-dollar basis we still see substantial increases in the interest and payments and grants categories, but national defense, both R&D and total, is actually below the levels of FY 1972 and FY 1967. Nondefense R&D, by contrast, is up almost 20 percent from FY 1972, although still below the peak Apollo year of FY 1967. For total R&D, real growth has averaged less than 1 percent per year since FY 1972, whereas the total budget has averaged a 5 percent per year increase.

President Carter's FY 1979 budget faces, at this writing, an uncertain fate in Congress. Congress will undoubtedly put its own election year marks on the tax reduction proposals and on spending plans in major controversial areas like energy and agriculture. However, the ordinary continuing operations of the government, including most R&D, will probably be less controversial. The figures in the FY 1979 budget will be subjected to many adjustments up and down as the authorization and appropriations committees do their work, but the budgets ultimately approved by Congress will probably not be radically different from the President's recommendations.

Chapter 2

R&D in the FY 1979 Budget

We shall begin our analysis of R&D in the FY 1979 budget with a statistical overview and then discuss the policies on R&D enumerated or reflected in the budget. Next, we will look at some topical highlights of R&D in the budget and finally at the R&D included in the budgets of the principal R&D agencies.

A. Statistical Overview

As we enter the world of R&D budget statistics, it is well to recall some cautionary notes. There is no R&D budget as such; the totals we will look at in a moment are the sums of estimates of the amounts for R&D in each of some 90 major agencies or subdivisions. Statistics are collected initially by OMB and later refined by NSF according to standard definitions which, however, rarely correspond exactly to agency accounting categories. The problems of statistical accuracy and consistency, while probably no greater than for most other social statistics, should discourage refined mathematical analyses. At best, the statistics show how much money has been or is proposed to be applied to R&D of a particular sort. They tell nothing of need, quality, or value of R&D. They do not distinguish between inherently high cost R&D requiring expensive equipment and logistic support, and R&D with lower costs. The meaning of increases or decreases from year to year depends on the circumstances in each case.

Even with these qualifications, R&D budget statistics, treated carefully, are a useful and sometimes the only means available for seeing and analyzing the broad picture of what is happening and planned in federal R&D. What do the statistics show for R&D in the FY 1979 budget?

Table 3 shows the overall totals, as estimated in terms of three principal financial measures: *budget authority* (appropriations), *obligations*

(contracts let, grants made), and *outlays* (expenditures, payments made). Outlays were the measure we used in our comparison of R&D to the total budget in Tables 2a and 2b. Obligations are traditionally used in OMB's "Special Analysis P" and in the analyses of the National Science Foundation. However, budget decisions in the Executive Branch and Congress are almost always made in terms of budget authority. Trends in budget authority reflect the policy changes embodied in each year's budget, whereas outlay trends lag a year or more behind decisions in budget authority, and obligation trends are sometimes distorted for fiscal and budget strategy reasons. We have, therefore, selected budget authority as the most meaningful measure of budget decisions and trends and used it wherever possible in this report.

In terms of budget authority, Tables 3, 4, and 5 show us that

(1) Total funds budgeted for FY 1979 for the conduct of R&D are up about 7 percent over FY 1978, to a level that is almost 70 percent above FY 1972 and FY 1967. In constant-dollar terms, however, FY 1979 is only 1 percent over FY 1978, only 6 percent over FY 1972, and actually 16 percent below FY 1967.

(2) R&D for defense purposes received the largest increase of the three major functional components into which federal R&D is divided in Table 4. In constant-dollar terms, however, R&D for defense purposes is still below the FY 1972 level.

(3) Total R&D for civilian purposes will continue to increase, but

Table 3. Total Federal Funding for R&D (in billions).

	FY 1967 Actual	FY 1972 Actual	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget
Current dollars					
Budget Authority[1]					
Conduct of R&D	$16.5	$16.5	$23.8	$26.0	$27.9
R&D Facilities	0.6	0.6	1.5	1.3	1.3
TOTAL R&D	$17.1	$17.1	$25.3	$27.4	$29.2
Obligations, Total R&D	$17.1	$17.1	$25.2	$28.0	$29.2
Outlays, Total R&D	$16.9	$16.7	$23.2	$26.2	$28.4
Constant 1972 dollars					
Budget Authority					
Conduct of R&D	$20.9	$16.5	$16.8	$17.3	$17.5
R&D Facilities	0.8	0.6	1.1	0.9	0.8
TOTAL R&D	$21.6	$17.1	$17.9	$18.3	$18.3
Obligations, Total R&D	$21.6	$17.1	$17.8	$18.7	$18.3
Outlays, Total R&D	$21.4	$16.7	$16.4	$17.5	$17.8

Source: "OMB Data for Special Analysis P" and *Federal Funds*, Volume XXV, NSF. Conversion to constant 1972 dollars by authors.

[1] In FY 1967 and 1972, authors' estimates based on obligation data.

only at about the same rate as inflation. As we will see later, real increases in some areas have been offset by tighter budgets elsewhere, especially for major demonstration projects.

(4) For basic research there is an overall increase in budget authority in FY 1979 of 11 percent over FY 1978, which in turn is now estimated to be 13 percent over FY 1977. In constant dollars, these increases

Table 4. Major Components of Federal Funding for Conduct of R&D (Budget Authority in billions).

	FY 1967 Actual	FY 1972 Actual	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget
Current dollars					
Defense	$ 8.6	$ 8.9	$11.8	$12.7	$13.8
Space	4.6	2.7	3.0	3.2	3.4
Civilian	3.3	4.9	9.0	10.1	10.7
TOTAL Conduct of R&D	$16.5	$16.5	$23.8	$26.0	$27.9
Constant 1972 dollars					
Defense	$10.9	$ 8.9	$ 8.3	$ 8.5	$ 8.7
Space	5.8	2.7	2.1	2.1	2.1
Civilian	4.2	4.9	6.4	6.7	6.7
TOTAL Conduct of R&D	$20.9	$16.5	$16.8	$17.3	$17.5

Source: Authors' estimates based on "Special Analysis P" and data from the Office of Management and Budget. Conversion to constant 1972 dollars by authors.

Table 5. Conduct of R&D by Character of Work (Budget Authority in billions).

	FY 1967[1] Actual	FY 1972[1] Actual	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget
Current dollars					
Basic Research	$ 1.7	$ 2.0	$ 2.9	$ 3.3	$ 3.6
Applied Research	3.0	3.9	5.6	6.2	6.6
Total Research	4.7	5.8	8.5	9.4	10.2
Development	11.8	10.7	15.3	16.6	17.6
TOTAL Conduct of R&D	$16.5	$16.5	$23.8	$26.0	$27.9
Constant 1972 dollars					
Basic Research	$ 2.2	$ 2.0	$ 2.1	$ 2.2	$ 2.3
Applied Research	3.8	3.9	4.0	4.1	4.1
Total Research	5.9	5.8	6.0	6.3	6.4
Development	14.9	10.7	10.8	11.1	11.1
TOTAL Conduct of R&D	$20.9	$16.5	$16.8	$17.3	$17.5

Source: "OMB Data for Special Analysis P" and *Federal Funds*, Volumes XXV and XXVI, NSF. Conversion to constant 1972 dollars by authors.

[1] Authors' estimates based on obligation data.

become about 5 percent and 7 percent respectively. We will discuss the trends in basic research in some detail later.

(5) Development and applied research, in overall terms, will increase by almost 6 percent in FY 1979; in constant dollars the total levels remain about the same.

Some additional R&D statistics are presented in Appendix A. Tables A-1 and A-2 show federal obligations for basic and applied research by field of science for selected years from FY 1967 to FY 1976, the most recent year for which actual data are available. Tables A-3 and A-4 provide a breakdown of total national expenditures for R&D by source and performer for selected years from 1967 to 1979.

B. R&D Policies in the FY 1979 Budget

1. Evolution

The policies affecting R&D in the FY 1979 budget took almost a full year to jell. True to the principles of zero-base budgeting, President Carter did not tip his hand on priorities for R&D until late November, when his final review of the FY 1979 budget was already well along. It was not until the State of the Union and budget messages were presented in January that the full outlines of R&D policy in the FY 1979 budget became known.

There were some advance but ambiguous signals. The President's decision to retain OSTP in the Executive Office and to appoint a university scientist as its director suggested that the President might have a positive attitude. But the heavy stress on zero-base budgeting to weed out government programs that do not meet real national needs sent apprehensive chills through the basic science community. These concerns were lessened somewhat when it became known that OMB Director Lance had sent a letter to the heads of departments and agencies asking them to be sure they were not short-changing basic research needs in setting priorities within their own budgets. There was some talk that additional funds for basic research might be found by deferring some large development or demonstration projects for a few months or a year. Suddenly, for the first time in recent memory, there were top level expressions of concern about R&D in industry; the science adviser raised the question whether the United States might be falling seriously behind other nations in innovativeness and met with industry leaders to discuss their views. University leaders discussed their research support and broader problems with the Vice President. The message that came through all this noise most consistently was that the President was not unsympathetic to R&D (or basic research), but felt that it should be justified by the problems it could help solve, not by the needs of universities, the desire to maintain levels of effort, nor the compulsion to do things because they were technically feasible.

The President's first public statement on R&D policy tended to confirm this message, with a small positive twist. He took the occasion of a Medal of Science ceremony to comment on his budget review sessions then in process. He said that many agency heads had "relegated R&D to a fairly low position of priority," but that he had "directed the OMB to boost those R&D items much higher and they will be funded accordingly." He mentioned having been impressed by the problems of scientific equipment and younger science faculty members. But he said candidly that his aim was not "to establish or maintain a college aid program." In his view, "to the extent that research and development commitments can be oriented towards things that improve the quality of our people's lives and enhance the security of our Nation, contribute to our position in world leadership, to that extent these allocations of funds will be more readily acceptable and supported by the American people."

2. *The Policies*

The formal policy statements that appeared in January were stronger and more specific. They are worth quoting in full. The State of the Union message, in an unusual special section on "Science and Technology" proclaimed:

> The health of American science and technology and the creation of new knowledge is important to our economic well-being, to our national security, to our ability to help solve pressing national problems in such areas as energy, environment, health, natural resources. I am recommending a program of real growth of scientific research and other steps that will strengthen the Nation's research centers and encourage a new surge of technological innovation by American industry. The budget increase of 11% for basic research will lead to improved opportunities for young scientists and engineers, and upgraded scientific equipment in the Nation's research centers. I am determined to maintain our Nation's leadership role in science and technology.

The budget message followed up a few days later with

> —*The Federal Government must lead the way in investing in the Nation's technological future.*
> Shortly after taking office, I determined that investment in basic research on the part of the Federal Government had fallen far too low over the past decade. Accordingly, I directed that a careful review be undertaken of appropriate basic research opportunities. As a result of that review, this budget proposes a real rate of growth of almost 5% for basic research in 1979. I believe this emphasis is important to the continued vitality of our economy.

In these two presidential statements and the supplementary materials on the FY 1979 budget, three main points come through loud and clear:

(1) A strong positive attitude towards science and technology. No defensiveness, no apologies. Science and technology are seen as a part of the solution, not the cause of our national problems.

(2) A special emphasis on basic research. The federal interest in basic research is termed an investment. Increased federal support is seen as necessary to correct underinvestment in the past.

(3) A new major stress on the economic justification of basic research and R&D generally. Continued advancement of basic knowledge in all fields of science is seen as essential to the future growth of the economy. The importance of basic research for the understanding and solution of other problems of national concern is fully recognized, but in the presidential statements economic benefits get top billing.

In the fine print and subsequent policy statements by the President's science adviser, there are several other significant policy points:

(4) Basic research is no longer to be regarded as a level of effort to be dealt with in overall terms and percentage changes, nor is the primary policy focus to be on the basic research supported by the National Science Foundation, as in previous years. There is a more sophisticated approach to basic research in the FY 1979 budget and special attention is given to basic research in agencies other than NSF.

(5) Policies on development and applied research, in nondefense areas, are considerably more restrictive than for basic research. In "Special Analysis P," OMB explains the slowdown in funding growth for "civilian R&D" in terms of three restraining policy considerations: the need for the federal government (i) to avoid "overtaking" activities that should be done in the private sector, (ii) to avoid investing in technology where user demand, economic viability, and institutional acceptance are unlikely, and (iii) to avoid overinvesting in multiple demonstrations of similar technologies or those that promise only marginal improvements.

(6) There is a new policy concern with a possible shortfall in industrial R&D, especially in basic and other long-term research. The budget document states the administration's belief that industry should strengthen its support of basic research. The science adviser has announced a major administration study of the whole range of problems relative to R&D in industry and the economy.

(7) For universities, the administration's policy is to support needed R&D, not to try to meet the problems of the universities as institutions. The problems of obsolescent equipment and lack of opportunities for young faculty are recognized, but not made the subject of special treatment; the administration's position is that they will be alleviated by the liberal increase in basic research funds, a large proportion of which will go to universities.

(8) The principal substantive initiative in R&D policy in the FY 1979 budget appears to be the new interagency programs of climate research, discussed below. While there are, as we shall also see, some

changes of policy or emphasis in other programs, in general the objectives and substance of federal R&D follow the paths anticipated in previous years.

3. Comments and Critique

What should be said about these policies as the new guidelines for federal R&D and for science and technology in the nation at large? First and foremost: the policies are positive, reasonable, and deserve wide support. The President, his science adviser, and OMB rate high marks for their handling of the most important concerns of science policy. They did not let zero-base budgeting kill R&D. They did not succumb to the antitechnology strain in some current intellectual attitudes. They found an acceptable rationale for continuing the upturn in federal support of basic science. Many questions and problems remain, but the scientific and technical community, Congress, and the public should have no major quarrels with the main thrusts of the R&D policies the Carter administration has presented with the FY 1979 budget.

A few other comments need to be made, not in criticism but as concerns for the administration and the scientific and technical communities to address in the future:

(1) The policy statements may go a little too far in tying the justification of basic research to economic benefits. A strong case can be made that a continuing, large-scale effort in basic research is needed to provide a flow of new knowledge on which economically significant innovations can be based. But as we will discuss in Part II, the linkage between basic research and its ultimate impact on the economy is long and loose. More sophisticated arguments are needed if one is to support the need for an increase in an already large-scale effort on grounds of future economic benefits. Until solid arguments are ready to be marshalled, there is the risk of exposing the whole basic research enterprise to the mercies of economic cost-benefit analysis. Highlighting the economic values of basic research should not be permitted to divert attention from or downgrade its many essential values that are not measured by economic indicators: improving the quality of life, understanding human, social, and national problems and finding ways to cope with them, and acquiring new knowledge as a value and end in itself.

(2) The policy statements on basic research can be read as open-ended, but in fact they say nothing about the government's future intentions. Is the boost for basic research in the FY 1979 budget a one-shot affair, or can similar boosts be expected in future years? How far will we need to go to remedy the "underinvestment" of the past decade? A longer-term policy and financial plan for basic research is needed to enable all concerned—students, scientists, universities, and federal laboratories and agencies—to base their plans on realistic expectations.

(3) There is an unfilled gap in R&D policy with respect to general applied research and technology development. At one end of the spectrum, basic research receives careful policy attention. At the other end, policies on applied research and development pointed toward specific ends are also reasonably clear; such R&D is generally industry's responsibility in the private sector and the government's responsibility where federal needs are involved or where federal intervention in the economy has been decided upon. The part of the spectrum in between—general applied research and technology development—is a policy no-man's land. Universities shy away from it. The federal government tends to leave it to industry and the market place unless a clear federal interest has been declared. Industry is reluctant to make the necessary long-term or non-product-oriented commitments, especially when there is a chance the government will pay for the R&D. So, while policy stresses the importance of basic research for innovation and economic benefits, an essential step for transforming the fruits of basic research into economic benefits is left in a policy vacuum.

(4) The R&D policies accompanying the FY 1979 budget leave some unfinished business in two areas of special concern to universities. The problems of obsolescent research equipment and research opportunities for younger scientists may need more direct action than the palliative spin-offs of a modest increase in basic research funding. A careful assessment and a better meshing of higher education and scientific research policies—on both the government and university sides—seem clearly needed.

(5) Federal R&D policy interest has tended to focus on the programs and funding levels to be approved. Now that the administration has clearly established a positive and sympathetic attitude towards R&D, it may be time to direct more attention to the management of R&D: how the funds are utilized, how program decisions are implemented, and how to relieve the ever-increasing burden of federal red tape that tends to choke off the productivity of federal R&D. What seems to be needed is a thoughtful look from a policy standpoint that recognizes the needs and problems of all parties concerned: the federal government, the research and technical institutions, and the working scientists and engineers themselves.

(6) A feature of the R&D policy statements accompanying the FY 1979 budget that has attracted special attention has been the emphasis on R&D, especially basic research, as an *investment*. This has been seen as something of a turning point in the federal attitude towards R&D, a recognition by the administration that R&D is not merely a year-to-year expense but rather an allocation of resources to produce long-term returns; that R&D is not something the government procures, but an enterprise it is in the government's interests to support; that there is need for a convergence of science policy with economic policy.[1] The President's science adviser has agreed with this interpretation of what the administration is attempting to accomplish.[2]

It will take much more than a verbal change in White House policy statements to transfer these basic changes in outlook to the way the government actually deals with R&D. The Office of Management and Budget will always be there and will have to respond to short-term budgetary exigencies as well as the calls of statesmanship. Zero-base budgeting won't go away. Congress may be supportive in principle,[3] but the deeply ingrained attitudes that surface when it comes to the actual appropriation of federal money will be hard to change. As for the hoped-for convergence of science and economic policy, the starting point is the fact that the President's *1978 Economic Report* and the *Annual Report* of his Council of Economic Advisers had not one word to say about the relevance of science and technology policy to the economic problems of the nation. There is a long way to go, but the President and his science adviser have set the right course and deserve full support.

C. R&D Budget Highlights

The real meaning of R&D budget policies has to be found in the budget figures themselves. We will try to capture some of the highlights in this section and then look over the R&D parts of the budgets of the principal agencies engaged in R&D.

1. Basic Research

Table 6 shows the amounts and trends in federal support of basic research, in current dollars and in constant 1972 dollars for each of the principal agencies involved. It documents the overall increase of 11 percent announced in the President's budget message and a constant-dollar increase of almost 5 percent. It also shows clearly that the administration's policies for FY 1979 did not start the upturn in basic research but rather continued the increasing trend started in FY 1977. As Dr. Press has pointed out, the decline since FY 1967 in the constant-dollar total was stemmed about 1975, and real increases were provided in President Ford's FY 1977 and FY 1978 budgets.

In the FY 1979 budget, special attention was given to basic research in the so-called "mission agencies" (meaning agencies other than those like NSF and NIH having scientific research as their major function) which were regarded as having "underprioritized" basic research in

---

[1] See William D. Carey, "A Policy Oriented R&D Budget," *Science* Vol. 199, No. 4330, 17 February 1978, p. 733.

[2] *Testimony by Frank Press before the Subcommittee on Science, Technology, and Space, Committee on Commerce, Science, and Transportation, United States Senate*, February 10, 1978.

[3] See, for example, Section 101(a)(4) of the "National Science and Technology Policy, Organization, and Priorities Act of 1976" (Public Law 94-282) and the "Federal Grant and Cooperative Agreement Act of 1977" (Public Law 95-224).

recent years. As mentioned above, Budget Director Lance sent a letter early in the budget review to the heads of these agencies urging them not to yield to the temptation to slash basic research in their zero-base budget reviews. The science adviser followed up in meetings with key agency leaders. This campaign seems to have been generally successful in avoiding the sacrifice of basic research to other needs; the statistics show most mission agencies continuing on the same increasing trends as in FY 1978. In some agencies there was a real "tilt" toward basic

Table 6. Conduct of Basic Research by Agency in Current and Constant 1972 Dollars (Budget Authority in millions).

	FY 1967[1] Actual	FY 1972[1] Actual	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget	Percent Change FY 1978 to 1979
Current Dollars						
HEW	$ 372	$ 461	$ 748	$ 860	$ 989	+15.0%
(NIH)	(309)	(381)	(669)	(763)	(856)	(+12.2%)
NSF	239	368	625	688	755	+9.7%
NASA	328	332	414	468	520	+11.1%
Energy[2]	302	268	390	433	468	+8.1%
Defense	284	270	290	320	364	+13.8%
Agriculture	100	137	195	235	252	+7.2%
Interior[3]	–	–	130	157	164	+4.5%
Commerce[3]	–	–	24	27	32	+18.5%
EPA[3]	–	–	21	21	30	+42.9%
Other	103	138	55	59	64	+8.5%
TOTAL	$1,728	$1,974	$2,892	$3,267	$3,637	+11.3%
Constant 1972 Dollars						
HEW	$ 471	$ 461	$ 529	$ 574	$ 621	+8.2%
(NIH)	(391)	(381)	(473)	(509)	(538)	(+5.7%)
NSF	302	368	442	459	474	+3.3%
NASA	415	332	293	312	327	+4.8%
Energy[2]	382	268	276	289	294	+1.7%
Defense	359	270	205	213	229	+7.5%
Agriculture	127	137	138	157	158	+0.6%
Interior[3]	–	–	92	105	103	−1.9%
Commerce[3]	–	–	17	18	20	+11.1%
EPA[3]	–	–	15	14	19	+35.7%
Other	130	138	39	39	40	+2.6%
TOTAL	$2,187	$1,974	$2,046	$2,179	$2,285	+4.9%

Source: "OMB Data for Special Analysis P" and *Federal Funds*, Volumes XVII and XXII, NSF. Conversion to constant 1972 dollars by authors.

[1] Authors' estimates based on obligation data.

[2] For 1967 and 1972, Atomic Energy Commission.

[3] For 1967 and 1972, these agencies were included in "Other."

research. For example, in the National Institutes of Health, the agency leadership made a major shift to more money for basic research and less for large-scale demonstration projects within a tight total budget. The emphasis on basic research in "mission agencies" is underscored by the fact that the increase accorded NSF, while substantial, was well below the average, in percentage terms, of all the other agencies.

2. *R&D at Colleges and Universities*

The amounts in the FY 1979 budget estimated to go for conduct of R&D at the nation's colleges and universities are shown in Table 7. An overall current dollar increase of 8 percent is foreseen, but the forecast rate of inflation of almost 6 percent will effectively whittle this back to less than 2 percent. Academic R&D will get increases well above the rate of inflation from the Departments of Energy (DOE), Defense, Agriculture, and Commerce and the Agency for International Development (AID). NSF estimates a smaller increase, and the largest single supporter of R&D at universities, the National Institutes of Health, will actually lose a little ground to inflation—another reflection of the tight overall budget given to NIH. Apparently, NASA's university clientele will have to absorb the full impact of inflation.

Table 7. Support for Conduct of R&D at Colleges and Universities (Budget Authority in millions).

	FY 1967[1] Actual	FY 1972[1] Actual	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget	Percent Change FY 1978 to 1979
HEW	$ 620	$ 916	$1,302	$1,716	$1,812	+5.6%
(NIH)	(478)	(756)	(1,298)	(1,495)	(1,571)	(+5.1%)
NSF	209	362	511	560	608	+8.6%
Defense	280	215	334	343	381	+11.1%
Energy	90	84	184	205	230	+12.2%
Agriculture	64	88	141	178	197	+10.7%
NASA	124	119	121	128	128	
AID	3	16	25	25	53	+112.0%
Commerce	6	24	29	33	37	+12.1%
Interior	23	25	24	33	34	+3.0%
EPA	–	18	30	31	33	+6.5%
Transportation	11	13	18	20	21	+5.0%
Other	24	22	24	27	31	+14.8%
TOTAL						
Current dollars	$1,454	$1,902	$2,942	$3,299	$3,566	+8.1%
Constant dollars	$1,840	$1,902	$2,084	$2,202	$2,238	+1.6%

Source: "OMB Data for Special Analysis P" and *Federal Funds*, Volumes XVII and XXII, NSF. Conversion to constant 1972 dollars by authors.

[1] Authors' estimates based on obligation data.

Table 8. U.S. Climate Program: FY 1979 (Budget Authority in millions).

	Impact Assessment	Diagnosis and Projection	Research	Observations	Data Management	FY 1979 Total	FY 1978 Total
Defense	$0.7	$4.2	$11.5	$16.7	$ 2.4	$ 35.5	$31.5
NSF	0.2	2.3	10.8	7.3	0.6	21.2	20.0
Commerce/ NOAA	0.8	1.1	5.0	3.8	9.3	20.0	11.8
NASA	–	–	–	13.8	0.9	14.7	2.5
Agriculture	1.4	•	0.4	3.6	•	5.4	5.2
Energy	2.5	0.3	1.0	0.7	–	4.5	3.0
EPA	0.2	–	1.8	–	–	2.0	1.7
Interior/USGS	0.5	–	0.5	–	–	1.0	.0
TOTAL, FY 1979	$6.3	$7.9	$31.0	$45.9	$13.2	$104.3	–
TOTAL, FY 1978	$4.9	$8.4	$26.0	$24.9	$11.5	–	$75.7

Source: "United States Climate Program: Fiscal Year 1979," OSTP (January 1978).
• Less than $100,000.

The standard vehicles for federal support of R&D at colleges and universities will continue in FY 1979 to be R&D project grants and contracts. The administration took strong policy objection to an institutional formula grant program added by Congress to NSF's FY 1978 budget on the grounds that any departure from the scientific merit criterion would be an irreversible step, undercutting and politicizing an established basis for federal support of research at universities which has won the confidence of Congress and the universities for the last 25 years. The President recommended, and the Congress has approved, reallocation of these funds to university-industry cooperative research, and no formula or institutional grant program is included in NSF's FY 1979 budget. A different approach was followed, however, with respect to an institutional formula grant program in NIH known as "Biomedical Research Support Grants." As a part of the annual tug-of-war between Congress and OMB on the NIH budget, OMB has traditionally excluded and Congress regularly inserted funding for this program. For the FY 1979 budget, however, a decision was finally made to include the amount of $40.6 million for the program under guidelines directed at what appeared to be special needs in the biomedical area. There is a policy inconsistency here for OSTP and OMB to iron out, but it seems clear that there is little likelihood of a general policy shift in the direction of institutional formula R&D grants for universities, especially in view of the President's declared opposition to the use of R&D as a "college aid program."

3. Climate R&D

The principal new interagency R&D initiative included in the FY 1979 budget is a $104.3-million, eight-agency climate research program, under the leadership of the National Oceanic and Atmospheric Administration. The participating agencies and the five main program categories are shown in Table 8.

Each agency is to continue working on aspects of climate problems within its normal scope of activities, but the establishment of a national program with a 38 percent funding increase over the corresponding activities in FY 1978 is intended to give this area the priority and attention that the scientific and technical community concerned has long believed it deserves. The work is to include

a. assessments of the impact of climatic variability on economically and socially important national activities;
b. diagnosis and projection of climatic fluctuations;
c. research to gain basic understanding of natural climate variability and potential human impact on climate;
d. observations by satellites and other means to help define climatic states and to investigate processes that determine climate and climatic variation;
e. data management required to support climate research and services.

Major funding increases in FY 1979 provide for (i) the development and procurement of satellite sensors for monitoring the earth's radiation budget, and ozone and ocean climate variables, (ii) a major field study in the Equatorial Pacific to investigate physical processes important to climatic fluctuations, and (iii) basic research on natural phenomena, particularly the effects of changes in carbon dioxide levels in the atmosphere and oceans.

4. Earthquake Research

The principal interagency R&D initiative in the FY 1978 budget involved the NSF and the U.S. Geological Survey (USGS) in a stepped-up program of earthquake research. The FY 1979 budget will carry forward this program, now being organized, at a level of $62 million that will be 17 percent over the FY 1978 amount and 158 percent above the FY 1977 totals for the corresponding activities. The increase will provide NSF with more funds for improving engineering of structures to withstand earthquakes. The USGS will continue its program of prediction research and regional earthquake hazard assessment.

5. Energy R&D

The Carter administration's energy R&D policies are based on the premises that (i) the contributions of R&D will be realized only in the

mid-term (1990–2000) and beyond, (ii) federal R&D should complement and augment, not displace, private sector efforts, and (iii) the risks of further international proliferation of nuclear weapons through the availability of weapons-grade by-products of nuclear power should be minimized.

In contrast to the ambitious package of initiatives in the non-R&D portions of the administration's energy plan, there are no major new directions proposed in energy R&D. As Table 9 shows, the total for direct energy R&D will remain approximately constant, with not even any increase for inflation, although changes in the program mix are recommended. Up to now, the Energy Research and Development Administration (ERDA) and the new Department of Energy have been unable in many areas to obligate the increased funds appropriated by Congress at the rate they have been provided. In this situation, a catch-up period for realigning priorities and improving management seems clearly needed; vigorous prosecution of energy R&D does not require a continuous spiral of higher budgets. Congress may not accept this approach, however; for example, efforts have already begun to increase

Table 9. Nuclear and Non-Nuclear R&D in the Department of Energy (Budget Authority in millions; includes plant and capital equipment).

	FY 1978 Est.	FY 1979 Budget
Direct nuclear energy R&D		
Fission	$1,053.3	$ 855.2
Breeder	(564.1)[1]	(367.4)
Fuel Cycle	(284.9)	(247.4)
Nuclear Research	(176.2)	(230.4)
Safety Facilities	(28.1)	(10.0)
Fusion	325.4	334.0
Subtotal	$1,378.7	$1,189.2
Direct non-nuclear energy R&D		
Conservation	$ 301.8	$ 386.0
Fossil	684.2	723.8
Solar	368.5	345.2
Geothermal	106.2	129.7
Biomass	20.7	26.9
Hydroelectric	10.0	8.0
Subtotal	$1,491.4	$1,619.6
TOTAL, Direct energy R&D	$2,870.1	$2,808.8

Source: Agency budget justification.

[1] Includes the $80.0 million for Clinch River in the FY 1978 supplemental appropriation.

the funds for solar energy research and to preserve the Clinch River breeder reactor project.

Continuing the trend started in the Carter amendments to the Ford budget last year, the FY 1979 budget places increased emphasis on non-nuclear energy R&D. For 1978, 51 percent of direct energy R&D is non-nuclear; in the FY 1979 budget this would increase to 57 percent. In the nuclear area, the major shift in policy is to reorient the breeder reactor program away from the Clinch River project and rapid breeder development to a more long-term effort. The total breeder program budget would be cut by $196.7 million, about $67 million of which is the net budgetary impact of the administration's renewed proposal to terminate the Clinch River project. The breeder program and other nuclear research, which is increased by $54.2 million, are now aimed at developing alternative types of breeder reactors and advanced reactor concepts consistent with the administration's nonproliferation objectives.

Conservation, geothermal, and biomass energy programs receive the most substantial increases in the non-nuclear area. Among fossil fuels, coal R&D increases slightly while efforts to develop new techniques for enhanced oil and gas recovery remain about constant. The overall amount for solar energy R&D decreases because of a reduction in funds allocated for solar heating and cooling demonstrations, but the R&D budget for thermal and electric applications of solar energy remains essentially constant.

6. *Environmental R&D*

Environmental problems are a major focus of federal R&D. In addition to the Environmental Protection Agency (EPA) several other agencies, notably the Department of Energy, NASA, and the Department of the Interior, carry out major efforts. Table 10 summarizes the total federal effort in environmental R&D. The total increases slightly in FY 1979, but not enough to keep up with the expected 6 percent inflation. Within the total there are shifts in emphasis. R&D in pollution control and abatement is cut back, but most areas of R&D directed at understanding, describing, and predicting various aspects of the environment are increased. Although not reflected in the overall totals in Table 10, the EPA made a policy decision in the FY 1979 budget to cut back on R&D concerned with ecological effects in favor of more effort on human health effects of pollutants. This shift is regarded as one of the outstanding cases where zero-base budget priority rankings caused a significant change in the FY 1979 budget.

7. *Competitive Grants for Agriculture R&D*

For the third straight year, attempts to enhance basic research on food and agricultural problems in the Department of Agriculture

(USDA) have been emphasized in the President's budget. These attempts have centered on the initiation in the Department of a competitive grants program that will bring a broader base of scientific talent in universities and elsewhere to bear on these problems of vital concern.

As shown in Table 11, the FY 1979 budget proposes a doubling of the Competitive Grants Program to $30 million, the same amount recommended in the FY 1978 budget but cut in half by Congress. The FY 1979 total is divided between $19 million for crop research, including research on photosynthesis, nitrogen fixation, genetic engineering and biological stress on plants, and $11 million for nutrition research.

Table 10. Environmental R&D in the FY 1979 Budget (Budget Authority in millions).

	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget
Pollution Control and Abatement	$ 818.8	$ 942.6	$ 918.9
Understanding, Describing, and Predicting	987.1	1,130.4	1,238.0
Observe & predict weather & ocean conditions	(231.8)	(245.8)	(262.9)
Locate & describe natural resources	(223.5)	(271.2)	(325.7)
Physical environment surveys	(22.9)	(31.7)	(30.3)
Weather modification	(20.2)	(17.2)	(14.3)
Environmental impact on humans	(270.4)	(320.9)	(335.2)
Ecological & other basic research	(218.3)	(243.6)	(269.6)
TOTAL	$1,805.9	$2,073.0	$2,156.9

Source: "Special Analysis O," FY 1979 budget.

Table 11. R&D in the Cooperative State Research Service, Department of Agriculture (Budget Authority in millions).

	FY 1978 Est.	FY 1979 Budget
Competitive Research Grants	$ 15.0	$ 30.0
Agricultural Experiment Stations	109.1	98.0
Formula grants	(81.1)	(73.1)
Regional Research funds	(24.5)	(21.7)
Other	(3.5)	(3.2)
Cooperative Forestry Research	9.5	8.6
1890 Colleges and Tuskegee Institute	14.2	14.7
Research	(14.2)	(14.2)
Other	–	(.5)
Special Research Grants	7.2	5.2
Rural Development Research	1.5	–
Administration	1.7	1.7
TOTAL	$158.2	$158.2

Source: Agency budget justification.

This program has had growing pains in the USDA and a rough time in Congress, partly because it has been regarded as competitive with the well-established programs of traditional agricultural R&D. The coincidence that, as shown in Table 11, the FY 1979 budget shows decreases in the politically popular formula grants to Agricultural Experiment Stations and other R&D exactly equal to the increase in competitive research grants may cause trouble in Congress again this year.

8. Health Research

Total federal outlays for health research are expected to increase by 6.6 percent (from $3.54 billion in FY 1978 to $3.78 billion in FY 1979), according to the OMB's special analysis of federal health activities. HEW will administer 77 percent of these funds; two-thirds of the total goes for the support of biomedical research through NIH. The largest supporters of health research outside of HEW are the Department of Energy, the Department of Defense, and the Veterans Administration, which together account for 12 percent of the total federal health research expenditures.

The budget request maintains current levels of effort for most of the major research areas. The areas singled out to receive substantial increases are basic research, particularly in NIH; developmental biology and behavioral and biological reproductive studies (including nutrition), as part of the administration's initiatives in child health assessment and the prevention of unwanted teenage pregnancies; and research related to mental health, alcohol, and drug abuse, reflecting recommendations of the President's Commission on Mental Health.

Within a total NIH research budget that is proposed to increase by only 3.5 percent, and therefore lose ground to inflation, basic research increases by 12.2 percent to $856 million. The decision to cut back on some popular disease centers, demonstration programs, and large clinical trials while increasing basic research demonstrates the priority given to basic research in this year's NIH budget. Only one institute at NIH is in line for a large increase, the National Institute of Child Health and Human Development, where a $33 million increase is tied to the special interest in child health and teen-age pregnancy prevention. Research in the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA) increases by 24.8 percent to $202.5 million in FY 1979. This increase, recommended in the interim report of the President's Mental Health Commission, reportedly took a special effort by the commission's honorary chairperson, Rosalynn Carter, to get it approved.

9. R&D in Education

For R&D in education, an OMB special analysis of all education-related programs, using a substantially broader definition of education

R&D than now used in R&D statistics, estimates total FY 1979 outlays at $668 million, $88 million above the FY 1978 level and $191 million more than was spent in FY 1977. Emphasis is to be placed on problems of educational equity and student outcomes. The Office of Education will increase funding for research on bilingual education, education for the handicapped, and the cognitive, emotional, and social development of "disadvantaged" children. The National Institute of Education—billed as the focal point of federal support for education R&D but second to the Office of Education in amount of funds provided—will increase studies in areas such as student achievement and testing, improved teaching, acquisition of basic skills, and urban education. Perhaps the most significant change at NIE, however, is the special emphasis given to basic research. In accordance with the recommendations of a study by the National Academy of Sciences on fundamental research relevant to education and the instructions of the National Council on Educational Research (the NIE policy-making body), NIE plans to earmark 20 percent of its FY 1979 budget for basic research. Between 3 and 5 percent of the budget would be set aside for unsolicited proposals.

Table 12. Estimated Federal Support for Social Science R&D (Budget Authority in millions).

	FY 1978	FY 1979
Department of Health, Education, and Welfare		
National Institutes of Health[1]	$ 40	$ 42
Alcohol, Drug Abuse, and Mental Health	162	202
Health Services Administration	16	16
Assistant Secretary for Health	40	34
Office of Education[2]	30	27
National Institute of Education	90	100
Assistant Secretary for Education[2]	1	1
Office of Human Development	76	80
Social Security Administration	13	15
Health Care Financing Administration	27	32
Assistant Secretary for Planning and Evaluation	30	27
Department of Agriculture		
Economics, Statistics and Cooperatives Service	37	39
Forest Research	18	18
Cooperative State Research Service	36	36
Department of Commerce		
Bureau of Census	3	4
Bureau of Economic Analysis	14	15
Economic Development Administration	37	40
Office of Minority Business Enterprise	2	4
NBS: Experimental Technology Incentives Program	4	4
Department of Defense (R&D on Human Resources)	68	75[1]

10. Social Science R&D

Although the budget materials do not include a compilation of federally supported social science R&D, we have attempted in Table 12 to estimate the approximate size of the social science R&D domain in the current budget. Our estimating has been guided by the definitions used in the recent comprehensive study of federal support for social science under the auspices of the National Academy of Sciences. These construe social science research as including basic, applied, or policy research on either the behavior of individuals, groups, or institutions or the effects of policies, programs, or technologies upon behavior; development is defined as including demonstrations and curriculum devel-

Table 12. *(continued)*

	FY1978	FY 1979
Department of Justice		
Bureau of Prisons: National Institute of Corrections	$ 10	$ 10
LEAA, National Institute of Law Enforcement and Criminal Justice	21	25
Department of Labor (includes primarily Employment and Training Assistance and OSHA)	33	40
Department of Housing and Urban Development	51	57
Department of State	3	3
Department of Transportation[2]	88	88
Agency for International Development	49	76
Department of Energy[3]	6	6
Environmental Protection Agency[1]	13	14
National Science Foundation		
Behavioral and Social Sciences	45	54
Science Education Development and Research	8	12
Science Assessment, Policy, and Planning	9	9
Information Science[1]	3	3
Applied Science and Research Applications[1]	23	23
TOTAL Estimated Social Science R&D[4]	$1,106	$1,231

Source: "OMB Data for Special Analysis P," *Budget Appendix, Federal Funds*, Volume XXVI, NSF, and *Survey Findings of the Study Project on Social Science R&D*, NAS.

[1] Authors' estimates.

[2] From "OMB Data for Special Analysis P." Budget authority data are not available for the broader classification of education research in "Special Analysis J."

[3] Based on agency estimate for socioeconomic research.

[4] Other agencies supporting some social science R&D, but for which data are not readily available are Agricultural Research Service, National Oceanic and Atmospheric Administration, Center for Disease Control, and Department of the Interior (largely the National Park Service).

opment; but statistics, program evaluation, and dissemination activities are excluded. Table 12 shows both the diversity of agencies and programs that support social science R&D and the major role of the large mission agencies in this area. Most social science R&D supported by the federal government has a distinctly applied nature, focused as it is on the societal problems that are the concern of the agencies supporting the work.

Major identifiable social science R&D programs receiving large increases in the FY 1979 budget are mental health, drug abuse, and alcoholism at ADAMHA; behavioral and social science research at NSF; education at NIE; fundamental behavioral and social research in DOD related in part to attrition and changing demographics in the all-volunteer forces; and social influences on human nutrition as part of the basic grants program in USDA.

D. Agency R&D Trends

We will now look at R&D in the federal budget in terms of the agencies that perform the work. First we will present the agency breakdown of the R&D totals we have already looked at. Then we will discuss briefly the R&D activities of each of almost a dozen of the principal R&D agencies. Detailed statistical tables on R&D in these agencies are included in Appendix B. We should note that the amounts in these tables often do not correspond to the amounts in our summary table; this reflects the fact that R&D in many cases is not managed or budgeted by the agencies in the same categories as those used by OMB and NSF for statistical purposes.

1. Agency Totals

The composition by agency of the OMB totals for conduct of R&D and R&D facilities is shown in Table 13. The tabulation is incomplete in a few respects. The R&D universe as defined by OMB excludes some agencies with R&D-related activities, such as the White House Office of Science and Technology Policy ($2.6 million) and the Office of Technology Assessment (OTA) ($10.0 million). Also excluded are "off-budget" agencies, for example, the U.S. Postal Service, which is conducting about $33.6 million of R&D in FY 1978. Two other kinds of R&D support are also excluded: tax savings to industry through special tax law provisions for R&D (estimated at $1.5 billion in FY 1979), and the allowances to private industry for performing independent R&D (IR&D) that are associated with some federal procurement and R&D contracts.

To sort out real trends from the effect of inflation we shall assume an inflation rate of 6 percent for FY 1979, approximately the rate

assumed in the budget. In addition, we will consider any R&D increase of more than 7 percent a "real" increase, and anything less than a 5 percent increase a "real" cut; increases between 5 and 7 percent will be regarded as "level."

In these terms, the total for conduct of R&D remains "level" after allowing for inflation; the total for R&D facilities decreases. In conduct of R&D, only four of the major agencies show "real" increases: Defense, NASA, NSF, Commerce; and six receive "real" decreases: Energy, HEW, Agriculture, EPA, Interior, and Transportation. Noteworthy large "real" percentage increases are also shown for some smaller R&D activities—AID, HUD, Labor, and the Nuclear Regulatory Commission (NRC). Excluding the four major agencies showing "real" increases, the combined total of the other agencies increases by only 4.0 percent in current dollars, a decrease in "real" terms.

2. *R&D in the Department of Defense (DOD)*

The recent reorganization of the Department of Defense established an Under Secretary of Defense for Research and Engineering as the primary official responsible to the Secretary of Defense for both R&D and systems acquisition, with the aim of integrating the management and policy for the entire R&D and production cycle. The 330-page unclassified statement by Under Secretary William J. Perry prepared for his congressional testimony on the DOD authorization and appropriation requests presents a detailed description of the philosophical and operational changes accompanying this reorganization, along with the general justifications for the research, development, test and evaluation (RDT&E) and procurement budgets. A brief discussion of selected Defense R&D items is based on this statement.

Table B-1 (Appendix B) shows breakdowns of the RDT&E budgets of DOD by category of work, performer, budget activity, and military department for FY 1977 through FY 1980. For FY 1979, $12.5 billion is requested for Defense R&D, a 9.2 percent increase over FY 1978. A further increase of 13.9 percent is projected for FY 1980. The total DOD budget is scheduled to grow by 8.9 percent in FY 1979, an increase regarded by many as inconsistent with President Carter's campaign promises to cut defense spending. When challenged on this point, administration officials reply that the FY 1979 request is $8.5 billion below that proposed by the previous administration for FY 1979.

Dr. Perry's statement bases U.S. defense R&D policy squarely on two cornerstones: our continuing competition with the Soviet Union and the central role of U.S. superiority in science and technology in this competition. Admitting that budget limitations prevent us from pursuing all the technological options, Dr. Perry argues that major emphasis should be placed on precision guided weapons because they have the greatest potential for multiplying the effectiveness of our forces. By

taking this approach, "we will effectively shift the competition to a technological area where we have a fundamental long-term advantage." Dr. Perry concludes his discussion of the need for investing in our technological lead by calling for increases in basic technology. The budget includes an overall 7.5 percent "real" increase in FY 1979 for the Science and Technology Program, which includes the categories of research and exploratory development, and part of advanced development. In real terms, research increases by 7.5 percent and exploratory

Table 13. Research and Development in the FY 1979 Budget by Agency (Budget Authority in millions).

	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget	Percent Change FY 1978 to 1979
Conduct of R&D				
Defense-Military Functions	$10,898	$11,756	$12,776	+8.7%
Energy	3,515	4,091	4,245	+3.8%
NASA	3,677	3,876	4,192	+8.2%
HEW	2,784	3,117	3,254	+4.4%
NSF	697	754	829	+10.0%
Agriculture	535	603	609	+1.0%
EPA	290	347	350	+0.9%
Interior	313	352	342	−2.6%
Transportation	314	336	342	+1.9%
Commerce	248	287	322	+12.4%
Nuclear Regulatory Commission	119	132	156	+18.0%
AID	51	49	76	+53.5%
Veterans	104	112	113	+0.7%
HUD	55	51	57	+11.1%
Justice	39	40	43	+8.1%
Labor	30	33	40	+22.1%
Smithsonian	30	31	33	+5.8%
Corps of Engineers	24	28	28	−2.5%
TVA	11	13	20	+61.9%
Treasury	4	6	7	+12.7%
Library of Congress	4	4	5	+9.3%
Civil Service Commission	4	4	4	
Consumer Product Safety Commission	4	3	4	+17.6%
FCC	2	3	4	+15.2%
ACDA	2	3	4	+42.3%
State	1	3	3	+3.6%
Advisory Commission on Intergovernmental Relations	2	2	2	+5.9%
FTC	1	1	1	
GSA	•	2	•	−93.3%
TOTAL, Conduct of R&D	$23,759	$26,039	$27,862	+7.0%

development by 4.6 percent, thus continuing the policy of approximately 10 and 5 percent increases, respectively, proposed for those two categories in the last three DOD budgets.

Two areas emphasized in the Science and Technology Program deserve special mention:

(1) A new Defense Science and Engineering Program is to be initiated in FY 1979 "to rekindle and stimulate the interest of the university science and engineering community in problems of national defense." The $9 million requested for this program is intended to put a special push behind the attempt to achieve better utilization of university research capabilities. This and the large overall increase in the research category should increase substantially the portion, now about 40 percent, of military research performed in universities.

(2) The Defense Advanced Research Projects Agency (DARPA) program receives an 11.6 percent "real" increase in FY 1979. DARPA's role in the DOD Science and Technology Program is "to explore the 'leading edge' of R&D and advance those technologies with potentially the highest payoff." The area proposed for large growth is "Experimental Evaluation of Major Innovative Technologies," which increases from $39.9 million in FY 1978 to $73.6 million in FY 1979.

Table 13. *(continued)*

	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget	Percent Change FY 1978 to 1979
R&D Facilities				
Energy	$ 639	$ 787	$ 804	+2.1%
Defense-Military Functions	580	174	238	+36.7%
NASA	118	162	152	−6.0%
HEW	90	86	45	−48.1%
NSF	27	37	39	+6.3%
Transportation	17	25	21	−17.6%
Agriculture	8	27	15	−43.3%
TVA	3	19	12	−39.4%
Commerce	5	8	4	−47.5%
EPA	2	0	3	
Interior	14	8	2	−75.6%
Smithsonian	•	1	1	+20.0%
Consumer Product Safety Commission	•	•	•	
Veterans	9	4	0	
TOTAL, R&D Facilities	$ 1,512	$ 1,338	$ 1,335	−0.3%
GRAND TOTAL, R&D	$25,271	$27,377	$29,197	+6.6%

Source: "OMB Data for Special Analysis P."
• Less than $0.5 million.

3. R&D in the Department of Energy (DOE)

The newly established Department of Energy brought together all the functions of ERDA, the Federal Energy Administration and the Federal Power Commission, as well as selected functions of the Departments of Interior, Navy, and Commerce and the Interstate Commerce Commission. All DOE functions are consolidated into ten primary missions in the FY 1979 budget; those missions that include R&D programs are shown in Table B-2 (Appendix B). The management of Department of Energy R&D programs is spread among six divisions, each headed by an assistant secretary: Energy Technology, Resource Applications, Conservation and Solar Applications, Environment, Defense, and Energy Research. All long-term technologies, such as solar electric and the breeder reactor program, are managed within the Division of Energy Technology, while work on marketable, currently available energy resources comes under two other divisions: Resource Applications, and Conservation and Solar Applications. This organizational pattern is intended to facilitate the introduction of new energy technologies into the marketplace. One effect, however, is to divide solar R&D between three divisions and conservation R&D between two, which leads to jurisdictional problems in Congress and criticism by solar energy proponents who want a focused effort on all aspects of solar energy.

As seen in Table B-2, total R&D in DOE remains about level in FY 1979. We have already discussed the highlights and trends in direct energy R&D (see Table 9). Some interesting features of the basic energy research, environmental R&D, and physics research programs are the following:

(1) The Division of Energy Research, comprising basic energy sciences, advanced technology and assessments, and high energy and nuclear physics, received a substantial increase in the FY 1979 budget. The basic energy sciences program, which is intended to expand the science and engineering knowledge base for new energy technologies, gets an overall increase of 19.2 percent. Within this increase is a request for $3.7 million for a new program of research in engineering sciences. Because of the importance placed on this program, DOE is attempting to reallocate funds to allow a small start in engineering research in FY 1978.

(2) Another new initiative is the advanced technology and assessments projects program for which $21.0 million is requested. The program includes the ongoing activity in assessing alternative systems to meet nuclear proliferation concerns, but it is to be greatly expanded to provide DOE with the capability to respond flexibly to new concepts, research needs, and innovative technological opportunities that are not undertaken in other Department of Energy R&D programs.

(3) The fundamental research activities in high energy and nuclear physics increase by 7.4 and 12.9 percent respectively. In high energy

physics, emphasis is placed on the new Isabelle accelerator at Brookhaven, the joint Stanford Linear Accelerator Center/Lawrence Berkeley Laboratory positron-electron project, and the energy saver at Fermilab; reductions are recommended for other parts of the program. In particular, the Argonne Laboratory's Zero Gradient Proton Synchrotron will be shut down by the end of FY 1979, all R&D programs not specifically related to the major new facilities will be reduced in size, and some reduction will be made in the operating levels of the Stanford Linear Accelerator and Alternating Gradient Synchrotron facilities. The increase in nuclear physics is spread throughout the program; a major item is the high intensity uranium beams project.

(4) In environmental R&D, the administration is requesting that DOE and EPA trade $14 million in programs. Activities that are concerned with clean-burning coal technology would be transferred from EPA to the DOE fossil fuel program. At the same time, health and environmental research projects would be transferred to EPA from DOE's environment R&D program, which would decrease by $9 million in FY 1979 to $209 million. Within the DOE environmental R&D program, research on the effects of increasing carbon dioxide levels in the atmosphere – part of the interagency climate program would double to a total of $3.1 million in FY 1979.

4. *R&D in the National Aeronautics and Space Administration (NASA)*

Although NASA and the White House Office of Science and Technology Policy did not complete a new statement of "national space policy" before budget decision time, the main outlines of the administration's thinking are reflected in the FY 1979 budget proposals and accompanying documents. In his State of the Union message, President Carter devoted a paragraph to the space program, mentioning continued development of the space-shuttle system, development of a spacecraft to study the polar regions of the sun, and increased emphasis on the practical applications of space-based systems and development of space technology. *The Budget* went on to say that increased emphasis will be given to the use of existing capabilities in contrast to the development of major new capabilities, other than the space shuttle, such as a large manned space station. In his statement on the FY 1979 budget, the NASA administrator, Dr. Robert Frosch, provided more insights into the thinking behind space policy. The philosophical underpinning is the investment nature of R&D mentioned in the President's budget message. NASA is applying two criteria in establishing priorities and allocating resources – usefulness to human life and intellectual importance – on the theory that investing in intellectual accomplishments and acquisition of knowledge will lead ultimately to long-term benefits for the American people.

Referring to Table B-3 (Appendix B), we see that the budget proposals for FY 1979 are consistent with the above policies. Space

science receives the largest increase of 26.8 percent; following in order are space and terrestial applications (16.2%), aeronautics and space technology (12.7%), and space transportation (4.4%). Some of the major items in the FY 1979 budget are these:

(1) The space shuttle program will be cut back from the initially proposed five shuttle orbiters to four. Funding for the space shuttle should begin to decline as the time for the first orbital flight in late FY 1979 approaches. Concomitantly, space flight operations expenditures will be rising as the shuttle goes into operation and costs for expendable launch vehicles will be diminishing as the shuttle takes over most NASA launches. If the NASA budget at least keeps pace with inflation, there is some hope that the completion of shuttle R&D and procurement will produce a "shuttle dividend" in future years that can be used for expanded-payload development programs in space science and applications.

(2) Four major new projects are proposed:

a. Solar polar satellite, to study radiation near the sun's polar regions ($13 million).

b. Earth radiation budget satellite, an activity in the U.S. Climate Program to study the net amount of radiation absorbed by the earth in particular regions ($8 million).

c. Halogen occultation experiment, to measure from a satellite the effect of chlorine on ozone in the upper atmosphere ($6.1 million).

d. Solar mesospheric explorer satellite, to study the effect of solar radiation on ozone in the mesosphere ($5 million).

(3) Provision is made for the increased funding required in FY 1979 to continue projects approved in previous years, including, for example, the Jupiter Orbiter Probe Program (rechristened Galileo), the space telescope, and the LANDSAT-D earth resources satellite.

5. R&D in the Department of Health, Education, and Welfare (HEW)

Table 14 shows the amounts for R&D for each of the organizational units within HEW. We will comment only on R&D in the National Institutes of Health and the Alcohol, Drug Abuse, and Mental Health Administration. The general picture in health research and HEW's R&D in Education have already been discussed in Section C-9 above.

a. R&D in the National Institutes of Health (NIH). As shown in Table B-4 (Appendix B), the administration has requested an increase of only $78.9 million (3.0 %) for R&D in NIH in FY 1979. The final NIH budget may well be higher because of the traditional congressional increases in the NIH budget. It could be that the expectation of such increases was a factor in the decisions on the NIH budget. Budget politics apart, however, the NIH budget does reflect important policy decisions. The small increase proposed for the National Cancer Institute is consistent

with a recent statement by the NIH director, Donald Fredrickson, implying a slowdown in the "war" on cancer: "There is no longer much question that the maximum utilizable funds are being devoted to research on cancer." As previously noted, the large increase in the budget of the Institute of Child Health and Human Development affirms the concern of the administration with problems of child health and unwanted teen-age pregnancies, and a major feature of the NIH budget is the increased emphasis on basic research.

Basic research funds increase from $763 million in FY 1978 (29% of the NIH R&D budget) to $856 million in FY 1979 (32% of the NIH R&D budget). To realize this increase will require a major reallocation of funds. The current plan for providing the $93 million increase in basic research is understood to include the following:

Table 14. Conduct of R&D in the Department of HEW (Budget Authority in millions).

	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget	Percent Change FY 1978 to FY 1979
Health				
National Institutes of Health	$2,240.3	$2,515.4	$2,602.6	+3.5%
Alcohol, Drug Abuse & Mental Health Administration	152.8	162.3	202.5	+24.8%
Center for Disease Control	53.8	57.9	59.1	+ 2.1%
Food & Drug Administration	41.0	47.0	47.0	–
Office of Assistant Secretary for Health	35.9	40.5	34.1	−15.8%
Health Services Administration	16.2	15.8	15.8	–
Special Foreign Currency Program	1.5	11.4	11.4	–
TOTAL (Health)	$2,541.5	$2,850.3	$2,972.5	+4.3%
Education				
National Institute of Education	$ 70.4	$ 90.2	$ 100.0	+10.9%
Office of Education	27.9	30.1	27.1	−10.0%
Office of Assistant Secretary for Education	1.0	1.0	1.0	–
TOTAL (Education)	$ 99.3	$ 121.3	$ 128.1	+5.6%
Welfare				
Office of Human Development	$ 70.1	$ 75.5	$ 79.5	+5.3%
Health Care Financing Administration	40.6	27.1	32.0	+18.1%
Departmental Management	20.0	30.0	27.0	−10.0%
Social Security Administration	12.1	13.1	15.1	+15.3%
TOTAL (Welfare)	$ 142.8	$ 145.7	$ 153.6	+5.4%
TOTAL (HEW)	$2,783.6	$3,117.3	$3,254.2	+4.4%

Source: "OMB Data for Special Analysis P."

(1) $25.5 million from reprogramming within each Institute. Demonstration projects and large-scale clinical trials will be cut back.

(2) $29.8 million from the overall increase in NIH funds.

(3) $20.3 million from restructuring the Biomedical Research Support Grants Program, such that 90 percent goes to basic research.

(4) $6 million from the funds saved by terminating institutional training grants.

(5) $11.4 million from the increase in the support activities (pay raises, etc.).

This funding plan does not give a unique role to the Institute of General Medical Sciences, the NIH institute that is devoted to basic research and research training. All the disease-focused institutes will share the new emphasis on basic research.

b. R&D in the Alchohol, Drug Abuse, and Mental Health Administration (ADAMHA). The ADAMHA research budget increases by 24.8 percent to $202.5 million in FY 1979, as shown in Table B-5 (Appendix B). This increase reflects the recommendations in the interim report of the President's Commission on Mental Health, which called for increased investment in mental health research. ADAMHA's budget justification stresses the importance of the agency attitudes to R&D: "In terms of both economics and ultimate results, a strong research program is the best investment that can be made in promoting our primary goals." Some areas of emphasis in the ADAMHA budget are the following:

(1) In mental health, there are increases in FY 1979 for mental disorders and maladaptive behavior; basic biological and developmental studies; social and cultural issues and problems; and mental health services research.

(2) Among the targeted areas in drug abuse research are endorphin research, sequential patterns of drug abuse, biological basis of addictive and habitual behavior, cigarette-smoking behavior, and the sequential patterns of drug abuse.

(3) The increase in alcoholism research is spread over several areas including fetal alcohol syndrome, genetic research, diagnostic and screening tests, and neurological mechanisms involved in alcoholism.

6. R&D in the National Science Foundation (NSF)

As shown in Table B-6 (Appendix B), the total National Science Foundation R&D budget is scheduled for a 9.5 percent increase to $875.4 million in FY 1979. R&D in the three basic science directorates, which include programs in the table from mathematical sciences through social sciences, would receive an overall increase of 9.2 percent, while basic research would go from $688 million in FY 1978 to $755 million in FY 1979, a 9.7 percent increase.

In the last three budgets (FY 1977 through 1979), the *proposed* increases in the basic sciences have been 19.5, 12.9, and 9.2 percent, respectively. In FY 1977 and 1978, congressional action reduced the

increases to 14.2 and 11.0 percent, respectively. Thus, barring an uncharacteristic congressional increase in the President's budget, the NSF basic science budgets will increase less in FY 1979 than in the past 2 years. However, NSF officials are said to feel that the FY 1979 budget is more "defensible" than last year's; perhaps Congress will not be so hard on NSF this year.

The increase in the basic science directorates is spread fairly evenly (although not on a formula basis) over all the programs. Notable large increases are proposed for some areas:

(1) Physics, where there are large increases in theoretical physics and elementary particle physics. The increase in particle physics will be used for conversion of the Cornell University synchrotron to an electron-positron colliding beam facility and for the equipment needs of NSF-supported users of the electron-positron colliding beam facility at the Stanford Linear Accelerator.

(2) Earth sciences, to allow for increased project support, especially in geochemistry instrumentation.

(3) Behavioral and neural sciences and social sciences, reflecting the National Science Board's positive assessment of new research opportunities, the need to strengthen the base of scientific techniques and resources, and the readiness of the scientists in these fields to make notable advances. NSF's emphasis on behavioral and social sciences is also reflected in the current plan for FY 1978; none of the congressional reduction in basic sciences was applied to these programs.

In applied research, the big news is the creation of the new Applied Science and Research Applications Directorate (ASRA) to replace the RANN program. ASRA is organized around five subactivities: problem analysis; integrated basic research; applied research; problem-focused research applications; and intergovernmental science and R&D incentives. Some activities in the RANN program were reassigned to ASRA or transferred to other NSF directorates. Several current RANN activities will be phased out during FY 1978 and 1979. However, unsolicited proposals in these areas will still be eligible for support under the applied research programs in ASRA. The programs slated to be phased out include

(1) Resources: nonconventional food research; resource development and conservation; and mineral processing technology.

(2) Environment: land use policy; societal response to natural hazards.

(3) Productivity: productivity measurement; distribution and equity; medical instrumentation technology; systems analysis; excavation technology.

7. *R&D in the Environmental Protection Agency (EPA)*

EPA is one agency that took seriously the President's request that zero-based budget techniques be used in the preparation of the FY 1979

Table 15. Conduct of R&D in the Department of Agriculture (Budget Authority in millions).

	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget	Percent Change FY 1978 to FY 1979
Agriculture Research Service	$284.4	$307.9	$316.8	+2.9%
Cooperative State Research Service[1]	129.0	158.2	158.2	–
Forest Service	90.8	102.2	98.6	−3.5%
Economic Research Service	26.9	30.2	31.2	+3.3%
Other	3.5	4.6	4.6	–
TOTAL	$534.6	$603.1	$609.4	+1.0%

Source: "OMB Data for Special Analysis P."
[1] Includes Competitive Grant Research Fund in FY 1978 and 1979.

budget. For the agency as a whole, the ranking and evaluation process resulted in a 12 percent increase in the total EPA budget (omitting construction grants) and a shift in priorities toward "major new commitments to protecting public health." As shown in Table B-7 (Appendix B), the research and development appropriation did not receive a similar budget increase, growing by less than 1 percent in FY 1979 to $324.1 million, but it was affected by the new emphasis on public health. Within the level R&D budget, R&D on health effects of pollution is increased – particularly R&D on the relationship of cancer incidence to environmental pollution, the effects of acid rain, and pollution exposure assessment models and methods.

The budget totals and trends for the Office of Research and Development are shown in Tables B-8 and B-9 (Appendix B) by media and program area. Except for a small amount of funds in pesticides and about $15 million in program management and support, all the funds in the research and development appropriation are allocated to this office. Health effects research increases by 30.7 percent with major increases in the areas of water quality, toxic substances, and energy. Environmental programs on health effects of energy production currently in DOE will be transferred to EPA. The anticipatory program increases from $4.7 million to $13.9 million in response to studies by the National Academy of Sciences and OTA that have indicated the need for increased long-term and anticipatory research to minimize the number and effects of unexpected environmental crises. The major decrease in R&D in EPA is in energy control and technology which goes from $91.6 million to $57.8 million. Two factors are responsible: (i) work begun in FY 1978 on the environmental impact of increased coal use and funded with a supplemental appropriation does not require the same level of support in FY 1979, and (ii) the transfer of some projects to DOE.

8. R&D in the Department of Agriculture (USDA)

The units in USDA that support R&D are shown in Table 15. The Cooperative State Research Service, the administrative home of the competitive grants program, was discussed above in Section C–7. Highlights of the R&D activities in the other units will be discussed here.

R&D in the Agricultural Research Service increases by only 2.9 percent, but there are significant changes within the total. Increases are provided for crop production research emphasizing small-scale farmers and integrated pest management; energy and water conservation; and human nutrition. Tobacco production research will be eliminated, and processing, storage, and distribution efficiency research will be decreased.

Changes in the R&D budget of the Forest Service causing the 3.5 percent decrease include increases for surface mine rehabilitation and the development of energy and petrochemical substitutes from biomass and decreases for forest and range management, forest protection, forest engineering, and resource economics research.

Increases in R&D in the Economic Research Service are for analyses of rural labor and credit; economic assessment of energy use, conservation and development in agriculture; forecasts of agricultural production and trade for foreign countries; and assessments of the economic feasibility of biological and cultural pest control and integrated pest management programs.

Two changes in the organization of R&D at USDA deserve mention. The Agricultural Research Service, Cooperative State Research Service, and Extension Service now fall within the new Science and Education Administration. Also, the Economics, Statistics, and Cooperatives Service was established to combine the functions formerly performed by the Economic Research Service, Statistical Reporting Service, Farmer Cooperative Service, and Economic Management Support Center.

9. R&D in the Department of Commerce

R&D in the Department of Commerce is scheduled to increase by 12.4 percent in FY 1979. As shown in Table 16, the National Bureau of Standards leads the way with an increase of 21.4 percent, while NOAA and the Economic Development Administration increase by 10.3 and 8.1 percent, respectively.

According to experts on committees that have studied NBS in recent months, the large increase in the NBS budget is just what is needed to stop the drift toward "mediocrity" and to fill the "gaps" in the Bureau's ability to carry out long-term programs. Saddled with a growing number of legislative assignments without concomitant personnel and budget increases to carry them out, NBS has been forced to sacrifice long-range programs for short-term objectives, which in turn

has begun to erode the basic scientific competence of the agency. Increases in the FY 1979 budget are aimed at rebuilding the state-of-the-art capabilities in basic science and engineering and will also provide for an expanded effort to establish standards and guidelines to enhance federal utilization of computers.

NOAA supports over half of the R&D in Commerce. As the focal point of the interagency climate program, it will coordinate all climate activities as well as increase the amount of its own climate-related research. Other areas to receive increases are research aimed at the conservation, development, and management of fisheries resources and endangered species and aquaculture R&D. The aquaculture industry is assuming new-found importance in the marine community, having been the subject of a National Academy of Sciences study as well as deliberations in Congress and Executive agencies. The Carter administration continues to wrestle with the development of ocean policy, and if the process goes according to plan, "oceans initiatives" are expected during 1978.

10. R&D in the Department of Transportation (DOT)

Table 17 shows that R&D in DOT remains approximately level in FY 1979. Some of the trends and program emphases in the DOT units that support R&D are these:

(1) R&D support in the Federal Aviation Administration declines by 3.9 percent. The R&D program is concerned with air traffic control systems, aircraft safety, aviation medical research aimed at increasing the effectiveness of traffic controllers, and environmental protection from aircraft noise and pollution.

(2) R&D in the Urban Mass Transportation Administration, which increases by 3.9 percent, will emphasize demonstrations of improved transit service, methods, and management techniques to encourage the improvement of current urban mass transportation systems.

(3) R&D in the Federal Highway Administration will increase by 5.8 percent. Attention is focused on increasing highway, vehicle, driver, and pedestrian safety.

(4) The 10.0 percent increase in National Highway Traffic Safety Administration R&D will go toward research on test-vehicle fabrication, development of an accident data base, fuel economy research, and obtaining data on damage to cars involved in severe accidents.

(5) The largest increase, 11.5 percent, in R&D in DOT occurs in the Federal Railroad Administration. Emphasis continues to be freight car management, improvement of freight services, safety of railroad operations, and improvement of railroad track structures.

(6) Coast Guard R&D remains level. Activities include the improvement of navigation safety and efficiency, design of methodology and equipment for passage in ice and iceberg-obstructed areas, and detection, identification and quantification of oil discharges.

11. R&D in the Department of the Interior

R&D in the Department of the Interior declines by 2.6 percent in FY 1979 as shown in Table 18. This decline results in large part from the decrease in R&D in the Bureau of Mines caused by the elimination of the Mined Land Demonstration Program. Related activities now fall within the responsibilites of the new Office of Surface Mining Reclamation and Enforcement, which will sponsor a program of applied re-

Table 16. Conduct of R&D in the Department of Commerce (Budget Authority in millions).

	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget	Percent Change FY 1978 to FY 1979
National Oceanic & Atmospheric Administration	$150.1	$164.7	$181.7	+10.3%
National Bureau of Standards	51.8	54.2	65.8	+21.4%
Economic Development Administration	15.0	37.1	40.1	+ 8.1%
Other	31.3	30.6	34.6	+13.1%
TOTAL	$248.2	$286.6	$322.2	+12.4%

Source: "OMB Data for Special Analysis P."

Table 17. Conduct of R&D in the Department of Transportation (Budget Authority in millions).

	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget	Percent Change FY 1978 to FY 1979
Federal Aviation Administration	$105.3	$110.6	$106.3	−3.9%
Urban Mass Transportation Administration	44.7	51.0	53.0	+3.9%
Federal Highway Administration	42.0	51.8	54.8	+5.8%
National Highway Traffic Safety Administration	39.8	41.8	46.0	+10.0%
Federal Railroad Administration	35.8	35.6	39.7	+11.5%
Office of the Secretary	19.9	15.5	12.5	−19.4%
Coast Guard	18.2	19.2	19.2	–
Research and Special Programs Directorate[1]	8.2	10.4	10.9	+4.8%
TOTAL	$313.9	$335.9	$342.4	+1.9%

Source: "OMB Data for Special Analysis P" and *Budget Appendix*.

[1] For FY 1977 and 1978, includes funds for activities in the Materials Transportation Bureau and the Office of the Secretary that have been transferred to the Directorate.

search on such subjects as the impact of water availability on mine reclamation practices.

Nearly half of the R&D in Interior is supported by the Geological Survey. In FY 1979, basic research programs will emphasize studies of the paleoclimate to identify long-term climate cycles, particularly drought frequency; movements of organics and other contaminants in water; and geomagnetism. Substantial funding will continue to be provided for the study of earthquake prediction and the assessment of regional earthquake hazards, although the level remains at about $30 million in FY 1979 after an increase of 158 percent in FY 1978.

12. R&D in the Agency for International Development (AID)

R&D in the Agency for International Development is difficult to identify for analysis. The statistics used in "Special Analysis P" are

Table 18. Conduct of R&D in the Department of the Interior (Budget Authority in millions).

	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget	Percent Change FY 1978 to FY 1979
Geological Survey	$128.9	$155.9	$162.5	+4.2%
Bureau of Mines	114.3	113.7	96.9	−14.8%
Fish & Wildlife Service	28.1	30.1	32.3	+7.3%
Office of Water Research & Technology	19.0	25.3	27.0	+6.7%
National Park Service	7.9	9.9	10.7	+8.1%
Other	14.7	16.8	13.0	−22.6%
TOTAL	$312.9	$351.7	$342.4	−2.6%

Source: "OMB Data for Special Analysis P."

Table 19. R&D in the AID Development Support Bureau[1] (Obligations in millions).

Functional Account	FY 1977 Actual	FY 1978 Est.	FY 1979 Budget
Food and Nutrition	$ 52.5	$ 59.3	$ 66.1
Population Planning	98.0	96.5	116.8
Health	4.4	6.4	10.0
Education and Human Resources	2.1	9.4	8.0
Selected Development Activities	2.6	11.5	12.5
TOTAL	$159.7	$183.1	$213.4

Source: AID Officials.

[1] Within each Functional Account, categories "Research," "Adaptations/Applications," and "Research Program Support Grants" are included.

evidently on a relatively narrow basis; substantially larger amounts could also reasonably be construed as R&D. Table 19 shows amounts that could be construed as R&D in the budget of the Development Support Bureau of AID according to functional account. R&D is also supported by AID's Geographical Bureaus, but data on the amounts are not readily available. AID is understood to be attempting to develop a system for better identifying these activities so as to obtain a more complete picture of its R&D enterprises.

The data in Table 19 show that R&D support in AID is scheduled to increase, particularly in food and nutrition, population, and health. This increase reflects the "new directions" for AID mandated by Congress in 1973 that emphasize transfers of knowledge, skills, and technologies applied to designated problems, rather than transfers of capital. Selected features of the current AID program are

(1) In the food and nutrition area the congressional mandate has been enhanced by Title XII of the Foreign Assistance Act of 1961 as amended in the Act of 1975, known as the Famine Prevention and Freedom from Hunger Amendment. In response to Title XII, large increases are requested in FY 1979 for strengthening the capabilities of U.S. universities in food and nutrition research and for long-term collaborative research between universities in the United States and the less-developed countries aimed at increasing production and improving distribution, storage, marketing, and consumption of food.

(2) The increase in population planning is spread among a variety of projects on fertility control and family planning. In an attempt to strengthen the relationship between population programs and other development assistance activities, centrally administered population activities have been combined with health, nutrition, education, and other development activities to form the Development Support Bureau. In addition, a new section has been added to the Foreign Assistance Act requiring all appropriate development assistance programs be designed with a view to "building motivation" for smaller families.

(3) The major increase in the health area is for research program support grants, which provide institutional funds to international R&D organizations.

(4) Funds in the selected development activities account provide support for such activities as development of appropriate technologies, remote sensing and satellite technology, research on nonconventional renewable energy resources, research on environmental protection and natural resource management, and study of the development process in order to learn more about the factors influencing economic development.

A new initiative in international R&D in FY 1979 is a joint U.S.–Israel Binational Agriculture Research and Development Fund to be administered by the Agricultural Research Service. Water and energy conservation research will be undertaken using the interest derived from an endowment established through contributions of $40 million

from each country. The U.S. contribution, however, is not included in the R&D statistics in "Special Analysis P" or in any of the tables in this report.

Looming large over the future directions of R&D and other aspects of foreign assistance is the question of AID reorganization. Several reports and studies are either completed or in progress, including AID's own internal review. A Brookings Institution study has recommended that all R&D, including that in the Geographical Bureaus, be pulled out of AID and administered separately. Before turning its attention to the Panama Canal Treaties, the Senate began to consider the late Senator Humphrey's bill that proposes to abolish AID and create an International Development Cooperation Administration with responsibility for directing all major development assistance programs. It is too early to predict what will come out of all this, but some reorganization of foreign assistance programs and its R&D components seems likely.

II

R&D, Industry and the Economy

Part II

Introduction

Part II of this report is devoted to the interrelated topics of R&D in industry and the impact of R&D on the economy. These topics take us outside the realm of R&D in the federal budget with which we have been concerned up to now; to understand the full range of R&D policy issues, or even the full range of issues in federal R&D, we must move to a broader perspective. In taking a look at industry-supported R&D we will be examining the largest segment of the national R&D effort not supported by the federal government, a segment that now represents about 45 percent of the total. In considering the impact of R&D on the economy we will be addressing questions that bear directly on the objectives and justification of most industry and much federally supported R&D. Taken together, and in the light of our analyses of federal R&D, the two topics—R&D in industry and the impact of R&D on the economy—provide a useful framework for addressing some of the fundamental policy issues R&D faces today.

Both of our topics are of interest from several different standpoints. R&D in industry is, of course, primarily the concern of industry itself. Questions of the allocation of a company's resources to R&D—whether, how much, and for what purposes—are major issues of corporate policy and management. The federal government is involved in several different ways. Almost half of its R&D is performed in industry. Federal R&D decisions must take account of the contributions industry-funded R&D can make to national needs, on its own or in cooperative arrangements with the government. Federal policies and regulations affect almost every aspect of industry R&D, with impacts ranging from encouragement and direct assistance to disincentives and stultification. Universities are interested in industry support for academic research and in industry R&D job opportunities for graduates and tenure-blocked junior faculty members. And, of course, economists, business analysts, and students of public policy have their professional interests in trying to understand what is going on and why.

The broader question of the relation of R&D to the economy is also the focus of diverse interests. Statesmen in both industry and government are concerned with the impact of R&D on particular sectors and on the economy as a whole. Economic policy-makers must choose among varying views on how much they can rely on R&D, government and private, to increase productivity, growth, and economic welfare. Economists must ask whether the impacts of R&D are properly taken into account in their theories and push ahead with their research on improved models and measurements. Federal R&D policy, especially on civil applications of technology, depends importantly on assumptions about the future impact of R&D in the economy. Finally, advocates and defenders who rely heavily on economic justifications for R&D need to reassure themselves and demonstrate to others that their faith in the economic value of R&D is well founded.

In what follows we shall attempt to recognize these many points of view, each of which reflects a legitimate interest within the AAAS and the community concerned with R&D and public policy. We cannot pretend to have examined, let alone digested, even a significant fraction of the vast body of data, studies, and opinions on these topics that are available, nor can we claim the expertise to pass judgment on the merits of the complex issues involved. Our standpoint has to be that of a concerned observer. Within these limitations, our objectives are

- to provide a compact overview of the current state of knowledge, opinion, and concern about the role of R&D in industry and the impact of R&D on the economy;
- to identify, sort out, and discuss briefly what seem to be the principal issues and problems as seen from the various standpoints mentioned; and finally
- to try to distill for special attention at the AAAS Colloquium the operative "bottom line" questions on which a better consensus is needed in the federal government, industry, the scientific and technical community, and the public at large.

Chapter 3

R&D in Industry

Research and development in American industry as an object of inquiry is more diffuse and harder to grasp than R&D in the federal government. In federal R&D, we have some 90 agencies or major subdivisions engaged in an enormous variety of R&D to the tune of about $25 billion per year. But there are some pretty good handles. The functions of each agency fairly well define the nature of its R&D activities. The agencies operate within the disciplines of the Executive Branch. There is a comprehensive annual budget. The R&D programs are publicly presented in great detail to Congress each year. Except when security intervenes, enormous amounts of substantive information and plenty of statistics are available to the interested and persistent inquirer.

In industry R&D, on the other hand, thousands of separate companies are involved, each with its own interests, objectives, and ways of doing business. The variety and size of the total effort is more bewildering than in the federal government. But there is no single President in charge, no hierarchy of agencies, no consolidated annual budget, no counterpart to the congressional review process. The competitive economy requires companies to play R&D cards close to the chest; information on industry R&D is guarded closely and doled out carefully, if at all. Statistics on industry R&D are generally sparse, out of date, and unverifiable, and must be used even more cautiously than federal R&D statistics. R&D in industry is more difficult to study than R&D in government, and the tools to study it are weaker.

The most comprehensive and detailed source of overall statistics on R&D in industry is in the annual series of National Science Foundation reports entitled *Research and Development in Industry*, produced jointly by NSF and the Bureau of the Census. Based on annual surveys, this highly professional statistical job maintains, and from time to time corrects, a series of financial, manpower, and other statistics on R&D in industry that goes back to 1953. Data are requested from industry on a

variety of interesting breakdowns, but much of the detailed information is not actually available because of incomplete survey responses or Census requirements to preserve the confidentiality of information on individual companies. Thus, many tantalizing matrices have more blanks than figures. Although this report is the standard by which other overall estimates are judged, it is primarily of historical interest because of the long time required for collection, analysis, and refinement of the statistics, and the inordinate publication delays. An advance *Highlights* report may appear 9 to 15 months after the end of the year reported, but it can be an additional 2 years or more before the full report is available.

More timely figures, giving total estimates for the current year but only a few first-order breakdowns, appear each summer in another NSF publication, *Patterns of National R&D Resources;* the overall totals have usually appeared in a precursor *Highlights* a few months earlier. Even more timely is the Battelle Columbus Laboratory's annual publication *Probable Levels of Research and Development Expenditures: Forecast and Analysis*, which appears the December preceding the forecast year. Other forecasts of the coming year's total industry R&D spending customarily appear in the January issues of the magazines *Research/Development* and *Industrial Research*. In some years (but not in 1977), the Industrial Research Institute (IRI) has published in the fall in its newsletter *Research-on-Research* a forecast of trends in industrial research for the following year. This forecast is based on informal surveys of IRI member companies and presents in terms of percent changes various aspects of their R&D funding and personnel over the past, current, and next following years. The only regular attempt at a longer-range forecast is the McGraw-Hill *Survey of Business Plans for Research and Development Expenditures*, usually published in May of each year, which provides estimates of industry R&D expenditures for the preceding year, the current year, and the third year in the future. Breakdowns by industry group and existing versus new-product R&D are presented, but no distinction is made between government and industry-funded R&D. The various estimates of total industry R&D spending are generally based directly or indirectly on the NSF estimates and do not differ markedly from them. Breakdowns of the total, by industry group and otherwise, however, show substantive variations—a clear reminder that all industry R&D statistics should be used with caution.

The only comprehensive source of R&D statistics on individual companies is the so-called 10-K filings most public corporations are required to make annually with the Securities and Exchange Commission. In 1976 and 1977, the magazine *Business Week* has performed the useful service of publishing the R&D-related information in the filings of some 600 companies, representing most but not quite all of industry R&D. Although only one R&D expenditure figure is given per corporation, and although the figures are known to have problems of definition and completeness, the totals of the *Business Week* listings are

within striking distance of NSF's corresponding estimates of the total R&D funded by industry. Trade journals and associations from time to time publish summaries giving company data on R&D in various sectors of industry, particularly those that are R&D intensive; *Chemical and Engineering News* and annual reports of the Pharmaceutical Manufacturers Association are examples. Probably the best source of substantive, but impossible to aggregate, data on industry R&D is in news stories in the financial pages of major newspapers and in the business press. The pronouncements of industry leaders and company annual reports on R&D, suitably discounted for self-interest, are likewise informative sources on what is going on or likely to happen in industry R&D.

A. Profile of Industry R&D

Using at face value the information and estimates available, let us begin by sketching the general picture they give of R&D in industry at the present time.

Industry's involvement in R&D is in two quite different modes, a distinction which is sometimes lost sight of and not always reflected in the statistics. About 35 percent of the total amount of R&D performed by industry is funded by the federal government. In this mode industry is selling R&D—in the form of hardware, studies, or services—to the government. In defense and space technology-oriented companies, for example, R&D itself is a big business; for such companies, R&D sales can represent a large fraction of total business, and maintaining a steady stream of government R&D contracts become a major corporate objective. In most other areas of industry, however, including some like the chemical and pharmaceutical industries that are heavily R&D oriented, the amounts of federally funded R&D are relatively small or even zero.

Industry R&D funded by industry itself is something else. Here R&D is a cost to be recouped, not by prompt reimbursement from a federal customer, but out of income earned from sales in the future. While federal tax laws permit company R&D expenditures to be written off as a current expense, the companies themselves must regard R&D as one of several investment alternatives for meeting future company objectives. R&D in this mode is a cost of doing and staying in business; as such, it has to stand the same scrutiny as all the other costs that enter into the balance sheet.

The overall dimensions of industry R&D in each of the two modes and of industry's role in the total national R&D enterprise can be seen in transfer tables of the type developed by the NSF in their annual reports on *National Patterns of R&D Resources* which analyze the total national R&D effort by both sources of funds and performer. Table 20 is a summary of the latest estimates on this basis, abbreviated to highlight the industry sector. It can be seen that industry is expected to perform almost $33 billion of R&D in 1978, representing almost 70

Table 20. Industry in the National Pattern of R&D, 1978[1] (in billions).

Source of Funds	R&D Performed by		Total
	Industry	All Others	
Federal Funds	$11.60	$12.24	$23.84
Industry Funds	21.20	0.28	21.48
Other Funds	–	1.68	1.68
TOTAL	$32.80	$14.20	$47.00

Source: National Science Foundation, data for *National Patterns of R&D Resources 1953–1978–79.*

[1] Amounts represent current operating costs, based on data reported by performers of R&D, and do not correspond exactly to the figures for R&D in the federal budget in Part I.

percent of the national total of $47 billion. Of the $33 billion performed by industry, almost $12 billion is in the mode of R&D sales to the government and $21 billion is funded by industry itself. Industry's own total investment in R&D is slightly higher, since it includes about $280 million spent by industry for R&D in universities and other nonprofit institutions. A hybrid type of R&D, "independent R&D" (IR&D), is presumably also included in the total for industry-funded R&D, perhaps as much as $500 million. This is company R&D the Department of Defense and other agencies allow as a reimbursable overhead cost on certain R&D and procurement contracts.

For manpower, NSF estimates suggest that industry is employing about 385,000 scientists and engineers in R&D work of all kinds, about 67 percent of the estimated national total of 566,000. Within industry about 120,000 (31%) are paid from federal funds and about 265,000 (69%) from company funds. The cost per R&D scientist or engineer appears to be systematically higher for government work by an average of about 35 percent.

International comparisons are tricky, but available 1975 statistics show both similarities and differences in the overall pattern of R&D in industry between the United States and other countries, as can be seen from Table 21. With respect to the portion of total national R&D that is performed in industry, the U.S. pattern is generally similar to that of the other OECD countries, that is, in the 60 percent to 70 percent range, with the notable exception of Canada (40%) and the possible exceptions of countries for which data are not available, including the United Kingdom, Italy, and the Netherlands, and except for a few of the smaller countries where the figure drops as low as 33 percent. The United States stands apart from the other nations for which data are available, however, in having a higher portion of business enterprise R&D that is funded by the government; the closest approach to the U.S. figure of about 37 percent is France's estimated 25 percent, with most of the others substantially lower. These percents are doubtless correlated

with the levels of defense R&D in each country; if United Kingdom figures were available they might approach the U.S. percentage.

There is no exact headcount, but the total number of U.S. companies engaging in R&D is estimated by NSF and the Bureau of the Census to exceed 10,000. They range from giants like General Motors, AT&T, Rockwell International, Lockheed, and IBM all the way to large numbers—estimated, not known—of small companies in specialized technologies or those just trying to develop and market a new product. About 1,200 of the companies engaging in R&D have 1,000 or more employees; these companies account for about 95 percent of total R&D expenditures in industry and provide the sample on which most of the available data on R&D in industry is based. Within these 1,200 companies, R&D expenditures are concentrated in a very few, with 100 companies accounting for almost 80 percent of the overall total, and the top eight companies representing almost 35 percent. NSF–Census statistics studiously avoid identifying individual companies, but the SEC public filings and government reports on Defense, NASA, and ERDA/Department of Energy R&D contractors make it a good guess that the top 10 in total R&D expenditures (in 1976–1977, the latest year of

Table 21. Total National and Business Enterprise R&D in Selected OECD Countries, 1975[1] (in billions of U.S. dollars)[2].

Country	Total National Expenditure on R&D	R&D Performed by Business Enterprise Sector			
		Government Funds	Enterprise Funds	Other Funds[3]	Total Funds
Canada (1975/76)	$ 1.76	$ 0.08	$ 0.58	$ 0.04	$ 0.70
Denmark	.40	.01	.15	*	.16
Finland	.23	.01	.12	*	.13
France	5.99	.93	2.51	.20	3.64
Germany	8.85	1.05	4.63	.20	5.88
Ireland	.06	*	.02	*	.02
Japan (1975/76)	8.77	.10	5.53	*	5.63
Norway (1974)	.26	.03	.10	*	.13
Sweden	1.22	.13	.68	.02	.83
Switzerland	1.20	.01	.90	—	.91
United States	34.59	8.76	14.78	—	23.54
TOTAL (above countries only)	$63.33	$11.11	$30.00	$ 0.46	$41.57

Source: Authors' estimates based on OECD 1977 materials.

[1] Data are for 1975 unless otherwise indicated. (Data are not available for United Kingdom, Italy, and the Netherlands.)

[2] National currency data converted to U.S. dollars by OECD at current exchange rates.

[3] Primarily funds from abroad.

* Less than $5 million.

record) are General Motors, IBM, Rockwell International, Ford Motor, Lockheed, AT&T, General Electric, United Technologies, General Dynamics, and Boeing.

There are several ways in which one can analyze total industry R&D to try to get some idea of which industries are doing how much R&D. The NSF–Census and other industry R&D statistics are usually presented according to the Department of Commerce Standard Industrial Classification (SIC); Table C–1 (Appendix C) shows some of the latest available NSF summary figures for government- and industry-funded R&D in industry. Another approach is to summarize, any way one wishes, the company-by-company totals for industry-funded R&D reported in the SEC 10–K filings; Table C–2 (Appendix C) summarizes the 1975 and 1976 filings according to the categories used by *Business Week*. In either approach, the figures for diversified companies have to be forced into a single slot; this means that whatever significance the category totals may have is distorted, especially by large conglomerates like United Technlogies and ITT whose subsidiaries have substantial R&D programs in different industry categories. Seeking to overcome this problem, NSF and Census also disaggregate the totals for applied research and development by product line. Their most recent published breakdown is presented in Table C–3 (Appendix C). Basic research in industry, which cannot always be related to a product line, is categorized by field of science as shown in Appendix Table C–4.

The significance of these statistics is hard to pin down. They confirm that on a dollar basis, government-funded R&D is concentrated in the areas of greatest interest to Defense, NASA and the Department of Energy—aircraft and missiles, transportation equipment, communications and electronics, and so on. On the industry-funded side, transportation (including the automobile industry), chemicals, and office machines (including computers) get some of the largest amounts. But size is not necessarily the same as significance, in R&D or anything else, and expenditure statistics are not a reliable measure of significance.

What, then, is the R&D that all these companies are doing? In the government mode, they are carrying out a major segment—about 49 percent—of the R&D programs of the federal government. They are developing weapons systems, space hardware, energy technologies, and new medicines; they are doing applied research and development on new technologies, new equipment, and new instruments; and they are building experimental and demonstration plants and federal R&D facilities. They are doing an enormous volume of paper studies of new concepts and design options, sometimes backing them up with experimental tests of crucial features. They are providing the government with a wide range of support services for federal research, development, test, and evaluation activities, ranging from full responsibility for the operation of laboratories and test centers to the provision of more specialized analysis, computational and other technical services. Industry is also performing some federally funded basic research, but the

amount is relatively small: less than 2 percent of all federal R&D performed by industry and less than 6 percent of all federally funded basic research.

The R&D funded by industry itself has a somewhat different complexion. A very few companies have traditionally supported broad programs of pure science only loosely coupled to their current business interests—the Bell Telephone and General Electric laboratories are outstanding examples. Many other companies have extensive and high quality research programs in technical fields directly related to their business concerns; for example, companies in the chemical, pharmaceutical, electronics, and computer industries, which had their foundations in scientific advances, typically maintain strong continuing research programs as a key element of business strategy.

A significant fraction of R&D in industry, perhaps over 20 percent, is directed toward the development of new products or the improvement of production processes to make existing products more efficiently. Most industry-funded R&D, however, is concerned with the actual design and development of the products to be sold—whole new product lines, new or improved products in existing lines, or simply new models of existing products. For industry, this is where the payoff comes, so this is where most of its R&D money goes. The engineering design and styling of each year's crop of new automobile models, for example, accounts for a major part of the $3 billion estimated annual R&D expenditures by the automotive industry; incremental improvements or changes for change's sake likewise characterize some of the R&D on many other consumer goods—the name of the game is to put something on the market that will sell.

Is all of this really R&D? From the perspective of academic basic research, the answer is sometimes a somewhat condescending "No." From the broader standpoint of R&D as a vehicle for innovation and economic benefits, however, the answer has to be at least "Maybe." One might play around with new definitions for gathering statistics that would separate out some new category of "real R&D." But our primary aim is not the refinement of statistical categories but rather to try to understand as best we can industry's scientific and technological activities and their impact on the economy. For these purposes we clearly need to consider R&D in its broadest sense.

B. Recent Trends

Now let us see what the available data can tell us about how R&D in industry has been changing in recent years. Even though one must have reservations as to the accuracy of any statistics on this subject, one may perhaps have more confidence in the significance of changes from year to year in data presumably collected or estimated on a comparable basis. For our analysis we have been fortunate to have been given access to the

Table 22. R&D Performed by Industry, by Source of Funds, 1967–1978 (in billions).

Sources of Funds	1967	1972	1975	1976	1977	1978
Current dollars						
Federal Government	$ 8.37	$ 8.01	$ 8.58	$ 9.20	$10.25	$11.60
Industry	8.02	11.51	15.52	17.42	19.15	21.20
TOTAL	$16.39	$19.52	$24.10	$26.62	$29.40	$32.80
Constant 1972 Dollars						
Federal Government	$10.59	$ 8.01	$ 6.75	$ 6.87	$ 7.25	$ 7.74
Industry	10.15	11.51	12.20	13.01	13.55	14.14
TOTAL	$20.74	$19.52	$18.95	$19.88	$20.80	$21.88

Source: National Science Foundation, data for *National Patterns of R&D Resources 1953–1978–79*. Conversion to constant 1972 dollars by authors.

revised NSF–Census Bureau figures on industry R&D for 1972 and succeeding years which will appear in *National Patterns of R&D Resources 1953–1978–79* and other NSF publications to be issued later this year. These revisions, based on resampling and follow-up questionnaires, have increased the previous estimates of total R&D funded by industry by factors ranging from about 1.6 percent in 1972 to almost 11 percent in 1977.

As shown in Table 22, total expenditures for performance of R&D in industry in 1978 are estimated at almost $33 billion, an increase of about 68 percent in current dollars since 1972 and 100 percent since 1967. In constant dollars, however, there has been no such dramatic increase, although NSF's revised figures do show an increasing trend of

Table 23. R&D Funded by Industry, by Performers of R&D, 1967–1978 (in billions).

R&D Performers	1967	1972	1975	1976	1977	1978
Current Dollars						
Industry	$ 8.02	$11.51	$15.52	$17.42	$19.15	$21.20
Universities and Colleges	.05	.08	.11	.12	.14	.15
Other nonprofit	.07	.10	.12	.12	.12	.13
TOTAL	$ 8.14	$11.69	$15.75	$17.66	$19.41	$21.48
Constant 1972 Dollars						
Industry	$10.15	$11.51	$12.20	$13.01	$13.55	$14.14
Universities and Colleges	.06	.08	.09	.09	.09	.10
Other nonprofit	.09	.10	.09	.09	.09	.09
TOTAL	$10.30	$11.69	$12.38	$13.19	$13.73	$14.33

Source: National Science Foundation, data for *National Patterns of R&D Resources 1953–1978–79*. Conversion to constant 1972 dollars by authors.

about 5 percent per year since 1975. This long-term trend is clear in the numbers for industry-funded R&D, but for federally funded R&D in industry there are increases above the noise level of the statistics and inflation correction factors only in 1977 and 1978. If we look back to 1967, we see there has been a decided shift in the mix: within only a 5 percent higher total constant dollar level in 1978, there has been an increase of almost 40 percent in industry-funded R&D and a 27 percent decrease in federally funded R&D in industry. The latter trend is clearly attributable to the passing of the peak years of NASA Apollo and Defense-Viet Nam R&D; the former documents a slow but steady real growth in industry's own total support of R&D over the past decade.

The same general trends are reflected in the breakdowns of the totals by type of performer (Table 23) and by character of R&D (Tables 24 and 25), with two apparent exceptions. These are basic research and industry R&D performed by universities.

Tables 24 and 25 show that the present levels of basic research in industry—both performed and funded—are substantially lower than in 1967, both in constant dollars and in percent of total industry R&D. Thus, Table 25 shows that, since 1967, industry-funded basic research has declined some 10 percent in constant dollars, while applied research and development together have increased more than 42 percent. It seems clear that industry has made a major shift away from basic research since the late sixties.

It is somewhat surprising, therefore, to find that the statistics do not show a corresponding decline in the relatively small amount of R&D funded by industry at universities. On the contrary, as seen in Table 23, the figures for total R&D funded by industry at universities for 1975–1977 have been at a level 45 to 60 percent above 1967 in constant dollars. For basic research only, the unrounded NSF statistics also show a level of industry funding at universities in recent years that is about 35 to 45 percent above 1967 in constant dollars. If all these statistics are correct, they indicate that from the late sixties to the middle seventies, industry cut back substantially its own performance and funding of basic research (in constant-dollar terms), while at the same time increasing its support of basic research (and all R&D) at universities. The percent of industry-funded basic research that is performed at universities, small though it is, has increased by 50 percent since 1967.

There is a growing body of opinion that the hallowed category of "basic research" is not very helpful in the analysis of R&D in industry. The argument is that industry's principal concern is with marketable products rather than with the nature of the technical activities needed to generate them. It is suggested that in lieu of the traditional basic-applied-development trichotomy it would be more meaningful to distinguish between R&D with long-term versus short-term objectives, or between R&D directed at new products versus that pointed toward improvements in existing products. There are few statistics on either of these bases, and the figures that exist are not very revealing. It is

generally accepted, however, and frequently stated by knowledgeable industry spokesmen or observers, that in recent years there has been a significant general shift away from R&D directed at long-term objectives and new products and toward R&D directed at short-term market objectives and the improvement of existing products.

Such a shift is barely perceptible—only two percentage points over 10 years—in the relative proportions of basic research to applied research and development in the NSF statistics for 1975–1977 summarized in Table 25; within that framework the shift to shorter-term work

Table 24. Character of R&D Performed by Industry, 1967–1978 (in billions).

	1967	1972	1975	1976	1977	1978
Current Dollars						
Basic Research	$ 0.63	$ 0.58	$ 0.72	$ 0.79	$ 0.84	$ 0.90
Applied Research	2.92	3.50	4.55	5.10	5.60	6.15
Development	12.84	15.44	18.83	20.73	22.96	25.75
TOTAL	$16.39	$19.52	$24.10	$26.62	$29.40	$32.80
Constant 1972 Dollars						
Basic Research	$ 0.80	$ 0.58	$ 0.57	$ 0.59	$ 0.59	$ 0.60
Applied Research	3.69	3.50	3.58	3.81	3.96	4.10
Development	16.25	15.44	14.80	15.48	16.25	17.18
TOTAL	$20.74	$19.52	$18.95	$19.88	$20.80	$21.88

Source: National Science Foundation, data for *National Patterns of R&D Resources 1953–1978–79*. Conversion to constant 1972 dollars by authors.

Table 25. Character of R&D Funded by Industry, 1967–1978 (in billions).

	1967	1972	1975	1976	1977	1978
Current Dollars						
Basic Research	$0.49	$0.55	$0.69	$0.74	$0.78	$0.84
Universities Only	(.03)	(.05)	(.07)	(.07)	(.07)	(.08)
Applied Research	1.89	2.61	3.42	3.89	4.29	4.70
Development	5.76	8.53	11.64	13.03	14.34	15.94
TOTAL	$8.14	$11.69	$15.75	$17.66	$19.41	$21.48
Constant Dollars						
Basic Research	$0.62	$0.55	$0.54	$0.55	$0.55	$0.56
Universities Only	(.04)	(.05)	(.06)	(.05)	(.05)	(.05)
Applied Research	2.39	2.61	2.69	2.91	3.04	3.14
Development	7.29	8.53	9.15	9.74	10.14	10.63
TOTAL	$10.30	$11.69	$12.38	$13.20	$13.73	$14.33

Source: National Science Foundation, data for *National Patterns of R&D Resources 1953–1978–79*. Conversion to constant dollars by authors.

presumably occurred within the applied research and development categories. The only overall statistics directly addressing the question are those in the annual McGraw-Hill survey, *Business' Plans for Research and Development Expenditures*, conducted and published in the spring of each year. The surveys for 1975, 1976, and 1977 show the percentages of R&D directed at existing products as essentially constant for the two years, current and preceding, shown in each year's report. On the other hand, these percentages have been increasing from year to year, from about 49 percent in the 1975 report to about 53 percent in the 1976 report and about 59 percent in the 1977 report. If the statistics are indeed comparable from one report to another, they could be reflecting the shift toward R&D on existing products that is believed to have occurred. However, one would also have to note that each year the survey respondents evidently did not forecast the shift that presumably was already underway at the time of the survey. This leads to the unsatisfactory conclusion that either the shift each year was not planned or the survey responses did not reflect industry's actual planning.

While the overall statistical support is weak at best, informed opinion, occasionally backed by statistics on individual companies, insists that industry R&D is increasingly focusing on short-term objectives and existing products. A rare example of a quantitative estimate is the reported statement by the DuPont company last year of an increase from about two-thirds to about three-fourths in the portion of the company's R&D expenditures going for support of existing businesses. The points most generally made are (i) that industry is becoming increasingly averse to taking long-term risks because of the uncertainties of inflation and government economic policies; (ii) that funds for R&D are tight because of squeezes on profits and competing demands of capital investment needs; and (iii) that government regulatory requirements—especially those regarding environmental effects and safety—have forced industry to reorient its R&D efforts to make existing products acceptable from environmental safety and other consumer standpoints.

There can be no doubt that there has been a major new emphasis on "defensive" R&D in industry in recent years. Well-known, but unquantified, cases in point include the large sums invested by the automobile industry on the development of emission control devices, the expenditures by the chemical industry on environmental improvements for products and processes, and the increased efforts in the pharmaceutical industry in research and testing of the safety and side effects of drugs and medicines.

The only effort to quantify the new emphasis on defensive R&D of which the authors are aware is that reported by the Industrial Research Institute in a November 1976 report giving its Research-on-Research Committee's *Forecast of 1977 Trends in Research*. Returns from about 60 IRI member companies indicated average compound annual growth rates from 1974 to 1977 of between 13 percent and 16 percent in several

categories of "Regulatory and Reactive" R&D activity (environmental considerations, OSHA requirements, and proposed legislation) compared to a corresponding average total growth in company-funded R&D of only 10 percent. Interestingly, the survey results showed no increase in emphasis in R&D efforts on safety considerations of products.

It is probably correct to presume that the increased emphasis on defensive R&D has resulted in increased emphasis on short-term company objectives and on existing rather than new products. But in the absence of comprehensive information permitting some quantification, this is not certain. We must not forget that industry's responses to regulatory requirements often include R&D on new products to substitute for existing products that are not acceptable (e.g., a new "pill" without bad side effects) and long-term R&D pointed to future product lines that could bypass the problems prompting the regulations (e.g., electric automobiles for urban use). Furthermore, a large proportion of industry R&D has always gone to short-term company objectives and the improvements of existing products. A new focusing of this R&D on defensive projects would not necessarily mean a significant shift in the mix of industry R&D between existing and new products or between short- and long-term objectives.

C. Future Outlook

1. Overall Trends

What can we say about the future outlook for R&D in industry? Various observers who have gazed into their crystal balls give differing reports of the overall trends.

Most forecasters see overall annual increases in industry R&D of 8 to 10 percent per year in current dollars and corresponding real growth in the 2 to 4 percent per year range. Thus, back in May 1977, the annual McGraw-Hill survey, without distinguishing between federal- and industry-funded R&D in industry, saw an 11 percent increase in total industry R&D in 1977 and a further 30 percent increase by 1980, all in current dollars. A year before, NSF's *1985 R&D Funding Projections* projected average annual real growth rates of 3.5 percent and 3.2 percent in industry R&D funding and performance, respectively, over the 10 year period 1975–1985. More recently and looking only at 1978, *Research/Development* magazine has forecast for industry R&D increases of 10.3 percent in funding and 8.2 percent in performance. *Industrial Research* magazine has taken a really up-beat view. Its editor believes a good case can be made for expecting a 5 percent gain in real dollars and that once industry "gets started on the energy market in a unified way . . . there is a possibility of vast infusions of private money into R&D" and the "increase could top 15 percent."

The Battelle annual forecast for 1978 is much more conservative. Battelle sees current dollar increases of 8.0 percent and 8.8 percent in industry R&D performance and funding, respectively, but also sees an increase of 9.2 percent in its cost of research index for industry R&D. This is 3 percent greater than the 6.2 percent increase forecast by the Carter administration in the GNP implicit price deflator which we have used in converting current to constant 1972 dollars. Battelle, therefore, forecasts a slight drop in total industry R&D in real terms. Battelle's 1977 estimates and 1978 forecasts of industry-funded R&D by industry SIC categories show real increases above Battelle's own cost index in only a few categories: professional and scientific instruments (6.3%), nonmanufacturing industries as a group (4.2%), machinery (2.2%), and the primary and fabricated metals categories included in "all other manufacturing" (2.0% and 2.4%).

The only available government forecasts of industry R&D covering both industry and federally funded portions are the NSF estimates for *National Patterns of R&D Resources 1953-1978-79* we have used in Tables 20 and 22 through 25 and discussed above. Compared to Battelle's estimates, the NSF projects current-dollar increases in 1978 of 11.5 percent in industry performance and 10.7 percent in industry-funding of R&D. With our conversion factors, the NSF estimates would provide constant dollar increases in 1978 in the 5 percent range. Battelle's factor would cut this to about 2 percent.

There is some indication that the trends projected by NSF may continue into 1979 and beyond. The Department of Defense is estimating current dollar increases in industry-performed military R&D of 13 percent in 1979 and 19 percent in 1980. Since DOD supports about two-thirds of federally funded R&D in industry, this increase should give the overall total a substantial boost, even with a leveling off of energy R&D and the lower growth rate in space R&D projected in the 1979 budget. For industry-funded R&D beyond 1978, no up-to-date estimates are available at this writing. By the time this appears in print, however, the 1978 annual McGraw-Hill forecast will presumably be available. If the usual pattern is followed, McGraw-Hill will give estimates for 1977 and 1978 and a forecast for 1981 of total R&D in industry, including, but not differentiating, industry and federally funded R&D.

2. *Federal Policy*

What is the outlook for industry R&D from the standpoint of the policies of the federal government that affect it? There is no easy answer because the federal government does not have a specific policy on R&D in industry as such. The best one can do is to summarize what the government says and does that affects R&D in industry and look at the pattern that emerges. The main elements seem to be these:

a. Reliance on Industry in Federal R&D. The government continues to place heavy reliance on industry to perform federal R&D. Ups and

downs in individual programs are unlikely to change the present pattern in which almost half of federal R&D is performed in industry. In the FY 1979 budget, as in all recent previous budgets, the general policy seems to have been to avoid expansion of in-house federal R&D whenever possible and to make maximum use of the private sector and existing federal capabilities.

b. National Importance of Technology and Innovation. Government policy statements give strong support to the importance of science and technology in general, and of innovation in industry in particular, to the national economy and to the leadership role of the United States. Thus, President Carter's State of the Union message in January 1978 makes the encouragement of "a new surge of technological innovation by American industry" the goal of his recommendations for "a program of real growth of scientific research and other steps to strengthen the Nation's research centers."

c. Government and Industry Roles in R&D. In civil areas where the government itself is not the ultimate user, the Carter administration, like the Ford and Nixon administrations before it, endorses the principle that the private sector *should* perform the necessary R&D at its own expense. This represents the application to R&D of the broader principle of the separation of government and private roles in the U.S. economic system; President Carter's strong statements in his State of the Union message on the limited role of the federal government in dealing with national problems put a new bipartisan stamp on this ideology.

In R&D, as in other areas, the actions of the government and industry often do not conform to the principles both sides accept, at least rhetorically, as ideal. The federal government has traditionally supported R&D directed at a wide variety of civil needs where the government itself is not the user—agriculture, atomic energy, health, space applications, civil aeronautics, for example. When new emergencies are recognized, like environmental and energy problems, a major part of the federal response is to step up R&D. So the general government policy that civil sector R&D should be done and paid for by industry and others in the private sector in practice comes down to little more than a presumption in favor of leaving R&D to industry unless the government decides otherwise.

To cope with, or at least rationalize somewhat, this discrepancy between general policy and actual practice, the Carter and previous administrations—principally through the Office of Management and Budget—have attempted to articulate guidelines limiting federal support of R&D in civil areas. From the statements accompanying the 1979 budget, it appears that the present federal R&D policies on the roles of government and industry are (i) "to avoid overtaking activities that are more appropriately those of the private sector, such as developing, producing, and marketing new products and processes" and (ii) "to emphasize longer-term (relatively lower cost) research for the future and new technology options rather than major commercial scale (and

relatively higher cost) demonstrations. For industry, this seems to mean that the government is trying to avoid competing in the market place and wants to off-load responsibility for commercial-scale demonstrations of new technology options.

d. Federal Encouragement of Industry R&D. Within the policy framework that R&D and innovation in industry are important to the nation but are primarily industry's own responsibility, the federal government provides a degree of encouragement to industry R&D. The patent system itself, tax provisions permitting industry to write off R&D as a current expense rather than as an investment (estimated to be worth $1.5 billion a year), and modestly supported technology-transfer programs to facilitate private use of the output of federal R&D are examples of long standing. The government-industry partnership in so much of federal R&D has also always had significant spill-overs into industry's own interests. While other government policies and actions – regulatory requirements, for example – may have, or may be perceived as having, effects that discourage R&D in industry, the basic posture of the government can fairly be described as positive but at arm's length.

There have been signs of more active federal interest in industry R&D during the first year of the Carter administration. Prompted by concerns about declining and defensive trends in industry, the President's science adviser stated that "one of my top priorities is stimulation of industrial research and the innovation process" and has gone so far as to call for "a new level of industrial R&D." Discussions have been held by the science adviser with industry officials to listen to their problems and encourage them to come up with some positive new ideas. But the most tangible action so far seems to have been the launching of a broad administration study of the health of industrial R&D, its link to innovation, the impacts of government policies, and changes that might be desirable in such matters as regulation, tax policy, antitrust constraints, patent policy, and so on. The study, which is to be under Department of Commerce leadership, has been very slow in getting underway; at this writing the intention is to have it completed in time to influence policy and budgetary decisions relating to the 1981 budget.

Serious attention was apparently also given to a proposal by the Department of Commerce to establish a new National Center for Cooperative Technology (NCCT) in the National Bureau of Standards. The concept of the NCCT was to provide a new federal mechanism for stimulating and assisting technological development in private industry. The proposal to proceed with a full-fledged NCCT organization and program evidently did not survive OMB–Presidental review in the 1979 budget process; all that remains in the budget as it went to Congress is a $2 million, low-key item to develop and refine an "approach to supporting U.S. industrial technology through a collaborative program with industry, universities, and other federal agencies."

About the only other new policy slant on R&D in industry advanced by the Carter administration appeared in a statement buried in the fine

print of the budget document. After justifying increased federal support for basic research on the grounds of underinvestment by the private sector, the anonymous author goes on to say: "The administration believes, however, that private investment in basic research is critical to the overall national effort and that industry also should seek to strengthen its level of support." This seems to represent little more than free hortatory advice from Uncle Sam; the NSF's subsequent announcement that it will be receptive to university proposals reflecting cooperative funding from industry may be another nudge in the same direction. The real-world effects, if any, remain to be seen.

3. *Industry's Outlook*

After having discussed the outlook for industry R&D as seen through the eyes of assorted statistical prognosticators and the federal government, it is time we asked about the views of industry itself. This is not an easy question. Industry speaks with many voices, and R&D in industry, taken as a whole, is even more of a statistical artifact than the notion of an overall federal R&D budget. Different industries and different companies have different outlooks. There can even be different views within a single company; the research director, the comptroller, the chief executive, and the members of the board of directors may have differing perceptions and views that have to be resolved to set or change company policy. Each company decides its own policies on R&D; the total trends we see are the net sum of all these separate corporate decisions.

An example of the variety of outlooks on R&D that can exist within a single industry at the same time is afforded by a *Chemical and Engineering News* report on the 1978 R&D plans of the leading U.S. basic chemical companies. The 18 companies reported indicated planned 1978 R&D increases covering the entire range from 3 percent to 25 percent. Assuming about 6 percent inflation, three of the companies (including the largest, DuPont) plan to cut back R&D in constant dollar terms, while nine companies are planning to increase more than 6 percent beyond the rate of inflation. The overall rate of increase for the group (8%) therefore conceals a wide diversity of company outlooks on R&D for the coming year.

Since industry controls its own decisions on R&D, one is tempted to say that industry must therefore agree that the overall trends in industry funded R&D are about right. If the trends are wrong, one could argue, industry itself would change them, by individual company decisions, to what they ought to be. What grounds can there be for criticism? A partial reminder may be found in the litanies of complaints, not limited to R&D, one hears from industry about undue government interference, excessive regulations, the capital shortage, high interest rates, and the uncertainties caused by the lack of consistent or constructive government policies that would enable industry to fulfill its potential in

the national economy. But if the "unreasonable" constraints and conditions were removed or alleviated and "reasonable" policies toward business put in force, would industry then actually make significantly different investments in R&D? Is it so clear, as is often implied, that industry should be investing more in R&D than it now is? How about the possibility that industry should be investing less?

There do not seem to be clear answers on these basic points. Perhaps there is no general answer. There may be some changed conditions under which each company, as it sees its own situation, would invest more. But is there a clear public interest to be served by a general increase in the level of industry R&D spending? We will defer discussion of this point; meanwhile, let us conclude our review of R&D in industry by noting a few of the points most frequently made by industry spokesmen.

a. R&D in Industry Is Different. Industry spokesmen keep reminding outsiders that R&D in industry is indeed a different animal from university research and that it does not fit comfortably into the traditional ways of looking at federal R&D. Distinctions between specific product-oriented and general R&D, between low-risk and high-risk R&D, and between R&D for short-term payoffs and R&D for long-term objectives are regarded as more meaningful than categories like "basic research," "applied research," and "development."

b. R&D Is Not the Same as Innovation. Industry people also keep making the point that innovations in industry depend on factors other than R&D. Innovation may require other kinds of capital investment. Decisions to undertake innovations depend on marketing judgments as to what will sell. Successful innovation may depend on R&D, but more R&D does not necessarily mean more innovation; conversely, a slowdown in innovations in industry does not necessarily mean that too little R&D is being done.

c. R&D Must Compete for Industry Funds. In a related point, industry constantly points out that the competitive and profit-oriented nature of U.S. industry means that there are always competing claimants for the resources that industry can apply to R&D. Needs and opportunities for capital expansion may deserve a higher priority than R&D, or than an increase in R&D. Stockholders may well prefer to see a higher rate of payout in current dividends than to have more earnings plowed back into R&D for the distant future.

d. Government Regulation and Constraints. A predominant theme in industry discussions of R&D is the unfavorable impact of government policies and regulations. The overwhelming burdens of paperwork; excessive and often picayune regulations on safety, employee relations, and so forth; excessive requirements for environmental and safety testing of new products; and financial and securities regulations that discourage new ventures are among the most frequently cited examples. One is tempted to discount these complaints somewhat; private industry always has and probably always will complain about too much govern-

ment interference. But there is no doubt that the conduct of R&D and all other aspects of business have been vastly complicated by the demands of the government and of the society at large which the government, sometimes imperfectly, represents. There remains, nevertheless, our earlier question whether, absent these troublesome burdens, the levels or orientation of industry R&D would be significantly different.

e. Government Assistance for Industry R&D? It is noteworthy that there has been no big push from industry for direct, general federal support of commercially oriented industry R&D. This is consistent, of course, with industry's traditional posture of opposing, in principle, federal subsidies or other direct involvement in the private sector. General principles notwithstanding, individual industries, from agribusiness to steel, are not bashful about coming to Washington for financial and other assistance. It is interesting, therefore, that there has been little industry clamor for general federal assistance to commercially oriented R&D. There are, of course, strong industry drives to secure federal R&D contracts, and industry generally supports federal R&D of direct benefit to it, as in aeronautics and agriculture. But most of the federal programs that have been started or proposed for the general advancement of technology in industry seem to have been the brainchildren of federal officials who believe they know what industry needs, rather than responses to urgings from industry itself. Does industry really believe it needs more R&D than it is now conducting?

f. Government and Industry Roles in Testing. One specific R&D related area where there has been some industry advocacy for direct financial assistance to industry has been in the testing of foods, medicine, and other substances for compliance with health and safety standards. The argument has been made by some in the pharmaceutical and chemical industries, for example, that current and prospective federal regulatory requirements with respect to possible carcinogens and other toxic substances require an increasing volume of extensive and costly tests over long periods of time. Since this is an undue burden for the companies and they would have to pass it on to consumers in the prices of the products sold, and since the tests are required by government regulations designed to protect the public at large, should not the federal government pay for the tests?

g. Concern About Long-Term Risks. Some industry statesmen, rising above the general complaints about government policies or lack of policies, express a much more fundamental concern: they perceive a general trend in industry to be more and more reluctant to take long-term risks. They see industry's decisions, not just in R&D, as increasingly colored by factors in the general outlook—continuing high rates of inflation, sluggish economic growth, the unpredictable course of the energy crisis, continuing uncertainties and vacillations in government policies—which tend to increase the risk and devalue the payoff of long-term ventures. They foresee the serious possibility of a domino-like

chain of effects: underinvestment by industry in long-range R&D, less innovation in U.S. industry, and a serious decline in U.S. competitiveness in world trade. Whether this trend is occurring or is about to occur in industry generally and what can and should be done about it, are among the questions we will return to later.

h. Industry and Basic Research. Lastly, what can be said about industry's outlook on basic research? Again, there are many views. Some companies, like AT&T, IBM, General Electric, and many smaller high technology companies, are fully committed to the importance and value to their companies of basic research, and they support it themselves in varying degrees. Enlightened management in many companies recognizes that the vitality of their product-oriented R&D depends on sustaining the quality and imaginativeness of their technical personnel and that this in turn depends on maintaining direct links with the advancing waves of basic research in the pertinent technical specialities. Some accept the view that the only effective link is direct participation in basic research itself. But a more widespread view appears to be, especially when one moves from company research directors to corporate decision-makers, that basic research is good and necessary but is not really industry's job. A typical company is not likely to get tangible benefits from basic research it supports, and the universities, with lavish support from the federal government, are going to do it anyway. Why get involved? The basic research focus of science policy is mainly a university and Washington phenomenon. As we have said, it remains to be seen how industry itself will respond to the urgings of the federal administration and a few industry leaders that industry support more basic research.

Chapter 4

R&D and the Economy

Let us now consider some of the broader questions of the impact of R&D on the economy, questions that go beyond R&D in industry and involve all R&D, government and private.

It is a generally accepted axiom that R&D is beneficial to the economy. Science and technology are universally given major credit for the economic development and growth of the United States in the 20th century. Almost everyone believes that R&D will continue to be a major essential factor for future economic growth and well being. But there are questions and differences on the exact nature of the relations between R&D and the economy and on implications for policy—for R&D policy in government and industry and for economic policy generally.

The R&D community often assumes oversimple cause-and-effect relations like "R&D helps the economy, so more R&D will help the economy more," and sometimes seems overly preoccupied with making the case for basic research. Industry tends to look at innovation more broadly, with R&D playing a significant but not controlling role. Economists trying to measure how and how much R&D helps the economy have not come to clear conclusions. There are gnawing doubts of the adequacy of traditional economic yardsticks and presumed relations. For example, is economic growth an adequate measure of economic welfare? Can we indeed count on R&D-induced innovation and growth to offset technological unemployment?

We shall examine these and some related questions briefly, from the standpoint of a concerned observer, and try to identify the key questions and issues.

A. How Does R&D Help the Economy?

The simplistic view is that R&D helps the economy through a sequence of events something like this: you start with basic research and

move on through applied research, development, technological innovation, increased productivity, and economic growth, and finally get a general advance in economic welfare. Of course, it's not that simple. It obviously is not an automatic progression or a linear chain of causes and effects. Everyone knows this, but the subtleties tend to get lost in discussions of R&D policy.

For example, *all* basic research does not (and should not be expected to) lead to applied research, development, innovation, and ultimately to an advance in economic welfare. It is also true that *no* basic research by itself causes an increase in economic welfare. It takes many other actions, and the external conditions have to be right, for this to happen. Nevertheless, oversimplified models of basic research, and R&D in general, as *causes* of advances in economic welfare are pervasive in current discussions of R&D policy. Oversimplification is unavoidable in general policy statements and in the rheto.ic of budget justifications. But the image of R&D as a lever that can be pulled to help the economy is also implicit in much serious thinking on R&D, especially in the government and academic wings of the scientific and technical community. Industry and economics perspectives, on the other hand, generally see the complexities more clearly and tend to be more cautious about the direct efficacy of R&D in he!ping the economy.

The dependency, especially in the long run, of technological innovation on R&D is not in question. The questions that deserve more consideration center on how and to what extent decisions on R&D can affect innovation. Here, as in other aspects of R&D policy analysis, it is important to disaggregate research from development.

Development is related to innovation in two ways. A decision in industry to introduce an innovation into the economy generally implies, as the next step, the development or completion of development of a new product or process. If this implementing type of development could be measured separately it might be a good index of the effort industry is putting into innovation at any particular time. Here it is the innovation decision that is causing development, not the other way around. But the more fundamental contribution which development (and R&D generally) makes to innovation is, of course, to provide the possibilities and options for innovation decisions in the first place. Technology development programs undertaken in government or industry without, or prior to, a decision to introduce an innovation into the economy provide a necessary part of the basis for such decisions when they are made. Thus, new technologies developed in military and space programs can provide ideas for adaptations or spinoffs into economically significant innovations, as well as absorbing much of the cost and reducing the risk. In some industries, materials and processes are developed without specific market objectives for the express purpose of providing opportunities for innovation decisions. In this mode, development makes innovaton possible, but still does not actually cause it to happen. A continuing high level of technology development

certainly increases the options for and likelihood of decisions for innovation in the economy. But whether decisions to innovate are actually made, and whether the innovations do in fact benefit the economy, depends on factors outside of R&D.

At the research end of the R&D spectrum, the relationship to innovation is usually more tenuous. In general, the results of basic research go into the general bank of knowledge and stimulate the never-ending cycles of discovery, analysis and synthesis. The contribution of basic research to innovation in the economy depends on a flash of insight by some individuals or groups—the research scientists themselves, engineers or inventors watching the results, or market-oriented people in industry—who see how the new knowledge can be put together with old to get a new product or process that will sell. At any given time, there are promising fields of research where possibilities for innovative applications can be clearly seen in advance (DNA research is a current example); in such fields increased research is likely to lead to more innovations in a shorter than normal period of time. Purists in universities to the contrary notwithstanding, there is such a thing as "targeted" basic research, and it does pay off in both scientific and practical terms. But even here it is not a sure thing. There is always the question of whether someone will make (or in a case like DNA, be permitted to make) the decisions to develop and introduce the innovation into the economy. There is also a time lag. Some estimates put the average time between basic research and resultant innovations at 30 to 50 years. The linkage between basic research and innovation is undoubtedly real and of crucial importance for the future. But except perhaps in a few cases where potential new applications are clearly seen in advance, one should not count on current decisions on basic research to have an appreciable impact on near-term problems in the economy. To claim too much too soon for basic research could undermine the credibility of its legitimate and essential longer-term claims.

Now let us consider how technological innovation leads to economic growth. There seem to be two mechanisms at work. Some innovations have the effect that products are produced more *efficiently*. In a competitive economy, such increases in productivity should result in lower prices; lower prices in turn should stimulate more demand; and more demand should lead to more production. These increases in production, plus those that should result from utilization elsewhere in the economy of the resources released by the increased efficiency of production, should bring about both an increase in the total productivity of the economy and overall economic growth. A second mechanism is at work when innovations involve the introduction of *new products*; here the interactions are more complicated. Demand for the new product can lead to increased production of the product, of the materials needed to produce it, and to imitations by other firms. These increases may be offset in varying degrees by declines in the demand and production of other products for which the new one is a substitute or which lose out to

it in the competition for the buyer's dollars. When the net effect is an increase in production and consumption, the result is overall economic growth. Through both of these mechanisms, innovation also makes a crucial contribution by helping our economy maintain or improve its competitive position in foreign markets. To the extent that increased efficiency and new products increase foreign sales of our products, there is an improvement in our balance of trade position and a positive contribution to our economic growth.

This shows, in a very superficial way, how innovation arising out of R&D can be expected to contribute to economic growth. Is this the whole story? Can we take economic growth, as usually measured by the rate of increase in GNP, as equivalent to the advancement of economic welfare? Not quite.

For one thing, there are aspects of economic welfare that are not reflected in the GNP. GNP figures do not tell us about the quality of goods and services or the degree to which economic and other needs are being met. However, one of the main contributions of R&D and innovation is to improve directly the quality of goods and services across the board—better consumer products, better military equipment, better health services, better communications, better business services, and so on. So R&D and innovation contribute to the advancement of economic welfare not only through their contribution to economic growth, but directly to other aspects of economic welfare as well.

Another aspect of economic welfare that must be considered is inflation. What is the effect of innovation on inflation? In general, the increased efficiency of new processes and technologies actually should result in lower real costs to consumers. The dramatic drop in overseas telephone rates with the introduction of satellite communications is an outstanding example: prices are lower even without correcting for inflation. In other cases the impact of innovation can be neutral or even inflationary, as when car prices are pushed up by the cost of new exhaust emission control devices. Federal expenditures for R&D or to encourage innovation presumably have the same short-run inflationary effects as other federal expenditures.

A final, and essential, aspect of economic welfare that may not always be assured by economic growth is full employment. If the rate of economic growth is high enough, it will eventually create enough new jobs to keep the increasing work force fully employed (under a reasonable definition of full employment). But if the growth rate is not high enough, for whatever reason, this key feature of economic welfare is not achieved. We need to ask whether R&D and innovation serve to promote full employment or work against it.

In many instances, an initial effect of a technological innovation is, inescapably, the creation of some unemployment. This can happen when the innovation involves a substitution of machinery for labor or when existing products or services are displaced by new ones. Two factors are generally counted on to counteract this short-run effect.

First, since unemployment increases the supply of labor, the cost of labor—in theory, at least—should go down, making a greater use of labor more attractive in other parts of the economy and thereby—still in theory—restoring full employment in the long run. Second, the new products and services resulting from innovation can be expected in some cases to provide new, previously nonexistent opportunities for employment. The new jobs so created can serve to offset those lost elsewhere, and once again, after a lag for readjustments all around, previous overall employment levels would be restored or even enhanced.

If things go according to this script, innovation would in general be neutral or even positive in its impact on employment. But when we ask if this is in fact the way things are working, we run into major uncertainties and differences of opinion. The realities of actual unemployment have increasingly called into question the economic theories which over the years have tried to lay the ghost of technological unemployment. Undoubtedly, different technological innovations have different effects on employment. What the net effect has been or, more importantly, what it is likely to be in the years ahead, we cannot presume to say; we have to log this as one of the principal questions for thoughtful and expert attention.

This is not the only uncertainty or loose coupling implied in our account of how R&D helps the economy. Let us conclude this section with a checklist of some of the key questions or issues that deserve further attention:

(1) What are the necessary and sufficient conditions for a continuing stream of innovations in the economy? We have seen that innovation depends on R&D but that the performance of R&D is not sufficient in itself for innovation to occur. We have to ask what the factors are that encourage or inhibit innovation.

(2) Can increases in productivity resulting from technological innovation be counted on to lead to overall economic growth? Increased productivity is clearly beneficial to the firm or industry where it occurs, but are the present and prospective workings of our economy such that the resources so released will in fact be utilized in other parts of the economy?

(3) Can we reasonably expect, in the years ahead, a continuing series of new products and services for which the demand in the economy will have the net effect of continuing overall economic growth? To the extent that the contribution of R&D to economic growth depends on innovation in the form of new products or services, this question is crucial.

(4) Is economic growth the right yardstick for measuring the impact of R&D on the economy? Even without broadening the definition of economic welfare to include social values like national security and the increase of knowledge, there should be some way of giving objective consideration to qualitative and other aspects of economic

welfare not adequately reflected in the GNP statistics. Without this, we may be seriously underestimating (or overestimating!) the contribution of R&D to economic welfare.

(5) Finally, to restate the question noted above: What will be the impact of R&D and innovation on employment in the years ahead? Is the technological unemployment caused by the introduction of innovation just a short-term phenomenon as theory would have it? Can other opportunities be counted on to take up the slack?

The answers to these troublesome questions are by no means clear. We do not have a corresponding list of answers, but we will try to move in that direction by taking quick looks, first at what help we can get from economic studies of recent experience, and then at the principal economic problems related to R&D and innovation as they are currently perceived in industry and government. In this way we will try to sharpen the operative questions on which policy-makers, experts, and actors, in industry and government, must make judgments and decisions.

B. What Do the Studies Show?

Much thought and study has been given, especially in recent years, to explaining and measuring the impacts of R&D and innovation on the economy. The central importance of technology to the development and workings of the economy is generally recognized by economists, although here, as elsewhere in economics, there are differing views on the interactive mechanisms and no fully satisfactory overall theories. A small but determined band of able economists has made the study of R&D and innovation in the economy a new field of specialization, bringing to bear the sophisticated tools of modern economics to try to gain a scientific understanding of how and how much R&D helps the economy.

Although few would claim that definitive results have been obtained, it is useful for our purposes to summarize the principal conclusions that can now be drawn. More detailed summaries of the present state of knowledge, with extensive further bibliographies, are in works cited in the List of References; however, the following may be especially useful: the papers presented at NSF colloquia on R&D and economic growth in 1971 and 1977; the National Academy of Engineering report "Technology, Trade, and the U.S. Economy," especially Chapter 2; and the article by Christopher Freeman in *Science, Technology and Society*, edited by Ina Spiegel-Rösing and Derek Price.

The principal points on a short list of conclusions would be these:

(1) "Advances in knowledge" have been the biggest single factor in economic growth and productivity gains in the United States over the past four decades. This conclusion of studies by Edward Denison and others appears to be generally accepted, although there are differing views on how the factors involved should be measured and evaluated.

(2) The rate of return on investments in R&D is generally high, both the *private* rate of return and the *public* or social rate of return. Private rate of return is a measure of the net profitability of an innovation to the innovator. Public rate of return includes also the economic benefits to users and others in the economy. Studies using different methodologies have found private rates of return for innovations generally in the 25 percent to 30 percent range, although the total dispersion is much wider. Public or social rates of return have been calculated to be about twice as great—over 50 percent. The rates of return are found to vary widely by industry. For example, much higher rates have been found for the chemical and petroleum industries than for the food, apparel, and furniture industries.

(3) High-technology, R&D-intensive industries have made an especially strong contribution to the economy. A recent Data Resources, Inc., study is reported to have found that over the past three decades these industries have on the average increased output, productivity, and employment several times as fast as low-technology industries, while raising their prices much less.

(4) Government-supported R&D has had a significant economic impact, but this is not clearly seen in the economic measures now generally used. Increases in the government's productivity are not reflected in standard GNP and growth accounting, since the output of government services is usually measured only by its cost. Attempts to measure "spill-over" effects of federal R&D expenditures in the private economy have yielded varying and controversial results, from zero or even negative to overall social rates of return of 40 percent or higher. Studies of federal R&D in civil sector problems have likewise shown results ranging from negative to decidedly positive. The fact seems to be that conceptual, modelling, and data limitations have prevented the development of a generally accepted way to measure the economic benefits of federal support of R&D. Attempts to surmount these difficulties have frequently involved reliance on dubious assumptions; for example, the assumption that there is a direct correlation between the *cost* of performing the R&D and the magnitudes of the *impacts* it may have in the economy.

It seems fair to say that the economic studies up to now, and the conclusions that can be drawn from them, do not go very far toward answering the key questions we identified above. The studies tend to confirm that R&D generally has beneficial effects on the economy, but they have not yet provided much on which to base either R&D decisions or economic policy. There are good reasons for this, as the practitioners in the field are fully aware, which deserve sympathetic recognition. First, the horrendous complexity of the problem. Second, the absence of an adequate theoretical structure which reflects the realities of the present U.S. economy and the ways in which technological changes affect it. Third, the difficulty or impossibility of getting the data needed—accurate data, current data, and data that are disaggregated

in ways needed for meaningful analysis. Fourth, the conceptual and practical problems of finding ways to measure outputs of R&D other than by its cost or other inputs. Finally, the problem inherent in learning from experience: does the past really tell us about the future? Will studies of the effects of R&D and innovation on the economy in the 1960s and early 1970s help us deal with the changing economic situations of the late 1970s and early 1980s?

C. R&D and Current Economic Problems

Let us conclude this chapter with a brief look at the current problems in the economy that are related to R&D and R&D policy. No reminder is needed that our top economic problems include high unemployment, increasing inflation, fear of recession, sluggish long term growth, distortions caused by price hikes of imported oil and other facets of the energy crisis, an international trade deficit, the declining value of the dollar, and an unacceptably low standard of living for much of our urban and rural populations. Where does R&D come in? What aspects of these problems can R&D policy affect? Some of the indicators found in the 1978 *Economic Report of the President, Science Indicators 1976*, and in other published materials seem to support the view that R&D considerations may indeed be relevant.

The principal indicator suggesting that what is or is not happening in R&D may be a significant factor in our economic problems is the decline in the rate of productivity growth. Official government statistics show a 46 percent decline in average annual productivity growth in the nonfarm business economy between the 1950–1968 and 1968–1977 periods. Even after correcting for cyclical factors, the 1978 *Annual Report of the Council of Economic Advisers* finds a 36 percent drop, from 2.5 percent per year to 1.6 percent per year. The present U.S. level is the lowest for any of the major industrialized countries and is said to be our lowest in 100 years.

As we have discussed earlier, economic doctrine relates productivity growth to economic welfare, both through its general contributions to growth in a competition economy and through its more direct contributions to our competitive position in international trade. Working back through our sequence of steps on how R&D helps the economy, we can say that the number and quality of technological innovations is a major (but not the only) determinant of productivity growth (others include increased skills in the work force and improved organization of production) and that R&D is a necessary (but not sufficient) factor in the development and introduction of innovations. This is the main line of reasoning that points to the level or nature of R&D as perhaps being one of the fundamental causes of the economic ills stemming from our reduced rate of productivity growth.

These considerations have led many responsible individuals in

industry and government to believe that U.S. industry may be "underinvesting" in R&D. There are many shades of opinion. One feeling is that external uncertainties and inhibiting government policies and regulations may be causing companies to underinvest in R&D even by the standard of their own self-interest; that is, by not investing more in R&D, they are building obsolescence into their products, plants, and processes and missing new opportunities for growth. Underinvestment in innovative R&D for the future appears to be aggravated by the shift within industry R&D to "defensive" and shorter-term R&D. Another view is that even if present levels and trends in industry R&D are appropriate for industry's own direct interests, they fail to provide the rate of innovation that the total economy needs in the overall national interest. As we have seen, this was the basis for the Carter administration's boost for federal support for basic research in the 1979 budget. The same reasoning, however, was not extended to applied research or development.

The view that the private sector may be underinvesting in R&D is not and perhaps cannot be clearly demonstrated by available economic indicators. But there are signs that can be taken as pointing in that direction, albeit not unambiguously. The fact that real growth in industry-funded R&D in the last decade averaged only 2 percent per year is frequently cited. However, the latest NSF–Census revisions to their estimates raise this figure to 3.5 percent; in any case, it is not clear that the absence of a larger rate of increase in annual outlays for R&D indicates underinvestment in R&D. A more pertinent indicator, perhaps, is the number of new venture companies seeking public financing to promote innovative ideas. These are said to have declined from over 100 per year in 1972 to virtually zero; risk-aversion, tight money markets, and over-regulation are usually given as the reasons. Other relevant indicators are the declining trend since 1971 in U.S. patents granted to U.S. residents, cited in *Science Indicators 1976* as a 26 percent drop from 1971 to 1976, and the decline in the number of major U.S. innovations, especially in "radical breakthroughs" in 1967–1973 as compared to 1960–1966 that was found in studies for the same publication. Finally, a strong theoretical argument has been made that industry will naturally underinvest in basic research and other R&D if the investing company is not likely to be able to "appropriate" the results for its own benefit.

Concerns about low productivity growth and a dearth of new innovations come into sharpest focus in the arena of international trade. There are clear indications that U.S. technological leadership is seriously threatened and already being eroded by foreign competition. U.S. productivity increases from 1960 to 1976 were below those of all other leading industrial nations of the world—France, West Germany, the United Kingdom and Japan. Even though U.S. productivity is still higher than the rest, the larger increases in productivity of France, West Germany, and Japan are improving their relative abilities to compete

with us. Even in high-technology, R&D-intensive manufactured products, where we have a highly favorable overall balance of trade, we already have a substantial trade deficit with Japan. Massive unemployment and cries for protectionism in hard-hit industries like steel are clear signs of a very real problem. The problems are aggravated by various built-in incentives to U.S. multinational companies to export technology and move production operations abroad and by subsidies and other forms of assistance foreign governments give to their companies competing with ours. Reduced productivity growth is not the only cause of our international balance of trade problems, nor is increased innovation and productivity a sure or sufficient cure. But it does appear to be a necessary ingredient in the package of measures needed to reverse present trends. To the extent that insufficient or misdirected R&D is holding back innovation, more or redirected R&D is a part of the answer.

While there is a strong and growing consensus on the seriousness of the economic problems—domestic and international—associated with the decline in productivity growth, there is much less agreement on the role of R&D, either as one of the causes of the problem or as a part of the solution. There are different views even in the highest circles. The President's State of the Union and budget messages stressed the importance of technological innovation to our economic well-being and the importance of new knowledge and basic research for technological innovation. On the other hand, the 1978 *Economic Report of the President*, issued a few days later, and the accompanying report of his Council of Economic Advisers, said not one word about the importance of technology or research and development. The economic high command acknowledges that the slowdown in productivity growth is one of the most significant economic problems of recent years. They point out that its causes are varied and hard to quantify, and they pin the blame mainly on the slower rate of growth in capital investment. But they do not mention, let alone single out, the need for changes in policies on R&D or innovation in their catalogue of recommended policy measures.

We may perhaps conclude that the fact that the situation is unclear even to the responsible experts gives all the more urgency to the early prosecution of the broad OSTP–Commerce Department study announced by the President's science adviser and to continuing efforts by private groups in industry and the scientific and technical community to crystalize their thinking and make known their views on this vital set of problems.

Chapter 5

The Bottom Line Questions

In our brief reviews of R&D in industry and R&D and the economy we have identified many problems and unanswered questions. We have seen that everything is related to everything else and that there are more unknowns and uncertainties than hard facts. Yet is is clear that serious matters are involved. After we have faced and accepted the complexities and uncertainties, what is to be done? Is there any alternative to an endless series of studies and discussions and a de facto policy of muddling through with incremental actions in the economic and political market places?

Perhaps not. But to help set the stage for the AAAS and other discussions that might lead to a clearer definition of alternatives, we will conclude this report with a listing of the "bottom line" questions that emerge from our analysis. Laid out in seven sets below, in their simplest form and without further discussion, are what appear to be the basic operative questions of fact and policy on R&D, industry, and the economy on which policy-makers and leaders in industry and government must make their judgments, either by conscious decision or by default.

Two general strictures apply to each of the seven sets of questions:

- First, the answers should address the future. The long lead-times involved in everything connected with R&D dictate that almost any new action or policy change will take effect in the world as it will be 5 or 10 years from now, not as it is today. We have to do our best to extrapolate our assessments of current problems and come up with answers to the problems of the 1980s, not the 1960s and 1970s.
- Second, the answers should try to disaggregate R&D and disaggregate industry. The most common fallacy in R&D policy discussions – to which the author has frequently succumbed along with everyone else – is to deal in terms of total

levels of R&D and of the industry as a whole. Even though the data and statistics are hard to come by, we should try to recognize in our thinking not only the conventional distinctions between basic research, applied research, and development, but also possibly more meaningful distinctions such as technology-driven versus need-driven R&D and short-, near-, and long-term R&D. Similarly, it is a misleading oversimplification to consider industry as a single entity. The Bell Laboratories and a struggling, new small innovative firm may be equal in the eyes of the law, but everyone dealing with R&D policy questions should try to make, or at least bear in mind, suitable distinctions of size, nature of business, relation to national needs, and so on.

The Questions

A. Factors Governing R&D and Innovation in Industry

(1) What are the factors that will govern the degree to which industry will invest in R&D in the next 5 years?

(2) What are the factors that will govern decisions in industry over the next 5 years on innovation, that is, on the development and introduction of new products and processes?

(3) If current restraints that inhibit R&D and innovation were removed or mitigated, would industry actually perform more R&D than now projected? Would more innovations be introduced?

B. Relationship of R&D to the Economy

(1) Given the current state of economic knowledge and opinion, what should policy-makers at this time accept as the probable relationships between the levels of U.S. R&D activity in the next 5 years and future economic trends? What impact can be expected from changes in R&D levels in industry and in government on

a. the introduction of innovations into the economy?
b. the rate of growth in productivity?
c. the rate of growth in the GNP and other measures of economic welfare?
d. the U.S. competitive position in world markets?

(2) Can we reasonably anticipate for the indefinite future a continuing stream of technological innovations that will generate new demands and lead to continuing economic growth? Are there any techno-

logical innovations waiting in the wings that are likely to have a major sustaining impact on the economy?

(3) Do we face serious problems of technological unemployment that will not be self-correcting in a reasonable period of time?

C. National Economic Requirements for R&D

(1) Is industry actually "underinvesting" in R&D? By business criteria? By national interest criteria?

(2) Should there be a major change in the present levels, trends, or composition of U.S. R&D? In federal R&D? In industry R&D?

D. Industry Actions

(1) What policy changes or other actions with respect to R&D in industry should be taken in industry? By industry associations?

(2) What policies or actions on R&D should industry urge on the federal government?

E. Federal Actions

(1) Should the federal government mount a major effort to remove inhibiting restraints on and provide encouragement to R&D in industry? Which specific restraints should be removed or modified? What types of encouragement are needed?

(2) Should the federal government extend its present rationale of supporting basic research as a spur to technological innovation to the support of applied research and general technology development in areas where significant innovations are likely?

F. Economic Justification for R&D

(1) In what ways and to what extent are the prospective economic benefits of R&D a valid justification for federal R&D budgets?

G. Future Studies

(1) Should government and industry take steps to generate more meaningful and more timely statistics or other information on R&D in industry and the impact of R&D on the economy?

(2) Is it reasonable and proper to expect industry to provide for

public information and analysis more meaningful, detailed, and timely information on its R&D plans and programs?

(3) What useful roles can the AAAS and other concerned private organizations play in advancing a constructive understanding, in both government and industry, of the interrelated problems of R&D in industry and the impact of R&D on the economy?

The hope is that by focusing discussions on these seven sets of questions, the AAAS will have taken a significant first step towards its goal of assisting responsible leaders in industry and government, and the concerned public, in dealing effectively with a difficult complex of problems of fundamental importance to the nation's future.

Appendix A

General R&D Statistics Supplementary Tables

Table A-1. Basic Research by Field of Science: Data Classified as in FY 1978 Budget (Obligations in millions)

	FY 1967 Actual	FY 1972 Actual	FY 1975 Actual	FY 1976 Actual
Current dollars:				
Life Sciences	$ 573	$ 668	$ 797	$ 878
Psychology	60	54	60	44
Physical Sciences	605	625	702	722
Environmental Sciences	209	291	339	355
Mathematics, Computer Sciences	65	63	59	70
Engineering	156	185	234	240
Social Sciences	57	80	73	85
Other Sciences	4	9	15	33
TOTAL	$1,729	$1,975	$2,279	$2,427
Constant 1972 dollars:				
Life Sciences	$ 725	$ 668	$ 627	$ 656
Psychology	76	54	47	33
Physical Sciences	766	625	552	539
Environmental Sciences	264	291	267	265
Mathematics, Computer Sciences	82	63	46	52
Engineering	197	185	184	179
Social Sciences	72	80	57	63
Other Sciences	5	9	12	25
TOTAL	$2,187	$1,975	$1,792	$1,812

Source: Federal Funds, Volumes XXV and XXVI, NSF. Conversion to constant 1972 dollars by authors.

Table A-2. Applied Research by Field of Science: Data Classified as in FY 1978 Budget (Obligations in millions)

	FY 1967 Actual	FY 1972 Actual	FY 1975 Actual	FY 1976 Actual
Current dollars:				
Life Sciences	$ 830	$1,236	$1,653	$1,768
Psychology	48	68	85	97
Physical Sciences	355	341	370	499
Environmental Sciences	173	270	393	416
Mathematics	65	74	78	83
Engineering	1,271	1,540	1,817	2,138
Social Sciences	131	231	231	305
Other Sciences	92	107	172	143
TOTAL	$2,965	$3,867	$4,799	$5,449
Constant 1972 dollars:				
Life Sciences	$1,050	$1,236	$1,300	$1,321
Psychology	61	68	67	72
Physical Sciences	449	341	291	373
Environmental Sciences	219	270	309	311
Mathematics	82	74	61	62
Engineering	1,608	1,540	1,429	1,597
Social Sciences	166	231	182	228
Other Sciences	116	107	135	107
TOTAL	$3,751	$3,867	$3,774	$4,071

Source: Federal Funds, Volumes XXV and XXVI, NSF. Conversion to constant dollars by authors.

Table A-3. National Funds for R&D by Source[1] (in billions)

	1967 Actual	1972 Actual	1978 Est.	1979 Est.
Current dollars:				
Federal	$14.4	$15.7	$23.8	$25.8
Industry	8.1	11.7	21.5	23.4
Univ. & Colleges	.3	.6*	1.0	1.1
Other Nonprofit	.3	.4*	.7	.8
TOTAL	$23.1	$28.4*	$47.0	$51.0
Constant 1972 dollars:				
Federal	$18.2	$15.7	$15.9	$16.2
Industry	10.3	11.7	14.3	14.7
Univ. & Colleges	.4	.6	.7	.7
Other Nonprofit	.3	.4	.5	.5
TOTAL	$29.3	$28.4	$31.3	$32.0

Source: NSF, data for National Patterns of R&D Resources, 1953-1979. Conversion to constant 1972 dollars by authors.

*Authors' estimates.

[1]Funds refer to current operating costs, based on data reported by performers. They do not correspond to the budget authority figures used in most of the tables in the text.

Table A-4. National Funds for R&D by Performer[1] (in billions)

	1967 Actual	1972 Actual	1978 Est.	1979 Est.
Current dollars:				
Federal	$ 3.4	$ 4.5	$ 6.6	$ 7.0
Industry	16.4	19.5	32.8	35.9
Univ. & Colleges	1.9	2.7*	4.6	5.0
Federal R&D Centers Administered by Univ.	.7	.8*	1.6	1.6
Other Nonprofit	.8	1.0*	1.5	1.6
TOTAL	$23.1	$28.4*	$47.0	$51.0
Constant 1972 dollars:				
Federal	$ 4.3	$ 4.5	$ 4.4	$ 4.4
Industry	20.7	19.5	21.9	22.6
Univ. & Colleges	2.4	2.7	3.0	3.1
Federal R&D Centers Administered by Univ.	.9	.8	1.0	1.0
Other Nonprofit	1.0	1.0	1.0	1.0
TOTAL	$29.3	$28.4	$31.3	$32.0

Source: NSF, data for National Patterns of R&D Resources, 1953-1979. Conversion to constant 1972 dollars by authors.

*Authors' estimates.

[1]Funds refer to current operating costs, based on data reported by performers. They do not correspond to the budget authority figures used in most of the tables in the text.

Appendix B

Agency R&D Budget Tables

Table B-1. Department of Defense Research, Development, Test, and Evaluation (RDT&E) (Budget Authority in millions)

Budget Activity	RDT&E Program by Budget Activity			
	FY 1977	FY 1978	FY 1979	FY 1980
Technology Base	$ 1,677.9	$ 1,797.0	$ 1,899.9	$ 2,192.0
Advanced Tech. Dev.	528.0	486.8	593.1	782.7
Strategic Programs	2,327.9	2,536.4	2,177.9	2,393.0
Tactical Programs	3,872.3	4,382.5	5,051.2	5,496.7
Intel. & Comms.	794.8	828.2	1,095.2	1,539.3
Programwide Mgt. & Support	1,387.2	1,381.7	1,550.7	1,795.0
TOTAL RDT&E	$10,588.1	$11,412.6	$12,468.0	$14,198.7

Category	RDT&E Program by Category			
	FY 1977	FY 1978	FY 1979	FY 1980
Research	$ 373.0	$ 412.1	$ 468.3	$ 545.3
Exploratory Dev.	1,305.0	1,384.5	1,531.7	1,646.7
Advanced Dev.	1,859.9	2,197.8	3,008.0	3,646.0
Engineering Dev.	4,079.1	4,389.9	3,933.4	4,299.6
Mgt. & Support	1,366.8	1,345.1	1,450.8	1,699.6
Oper. Sys. Dev.	1,604.3	1,682.9	2,075.8	2,361.5
TOTAL RDT&E	$10,580.1	$11,412.6	$12,468.0	$14,198.7

Table B-1 (continued)

Department	RDT&E Program by Component			
	FY 1977	FY 1978	FY 1979	FY 1980
Army	$ 2,290.7	$ 2,418.3	$ 2,721.4	$ 2,958.0
Navy	3,800.1	4,021.8	4,490.5	4,762.4
Air Force	3,816.0	4,193.2	4,339.1	5,293.4
Defense Agcys./DT&E	681.3	779.3	917.0	1,184.9
TOTAL RDT&E	$10,588.1	$11,412.6	$12,468.0	$14,198.7

Performer	RDT&E by Type of Performer			
	FY 1977	FY 1978	FY 1979	FY 1980
Industry	$ 6,967.0	$ 7,749.5	$ 8,777.5	$10,460.2
Government In-House	3,102.3	3,126.8	3,129.4	3,138.0
Federal Contract Research Centers (FCRC)	190.6	205.4	212.0	237.4
Universities	328.2	330.9	349.1	363.1
TOTAL RDT&E	$10,588.1	$11,412.6	$12,468.0	$14,198.7

Source: Program for Research, Development, and Acquisition, statement by the Honorable William J. Perry, DOD, 1978.

Table B-2. R&D in the Department of Energy (Budget Authority in millions; includes plant and capital equipment)

	FY 1978 Est.	FY 1979 Budget
DOE Missions Containing R&D		
1. Energy Supply - Research & Technology Development (R&TD)	$2,743	$2,670
2. Energy Supply - Production, Demonstration, & Distribution (PD&D)	66	36
3. Conservation	302	386
4. Environment	218	209
5. Basic Sciences	397	426
6. Atomic Energy Defense Activities	1,122	1,206
TOTAL, DOE R&D above	$4,848	$4,933
1. Energy Supply - R&TD (all R&D)		
Fossil	($684.2)	($723.8)
Coal	579.1	618.2
Petroleum	74.1	79.7
Gas	31.0	25.9
Solar	(302.7)	(309.2)
Thermal applications	40.4	45.1
Technical support & utilization	9.0	14.1
Solar electric	253.3	250.0
Geothermal	106.2	129.7
Magnetic fusion	325.4	334.0
Fuel cycle	284.9	247.4
Breeder reactor	(564.1)	(367.4)
Clinch River	80.0[1]	13.4
Fast flux project	126.9	70.1
Breeder technology	213.6	127.0
Technology integration studies	---	15.0
All other	143.6	141.9
Nuclear research & applications	(226.7)	(278.5)
Water cooled reactor	41.7	63.0
Gas cooled reactor	48.0	63.0
Light water reactor technology	18.8	23.9
Technology development & special projects	16.1	4.9
Space applications	34.4	43.2

Table B-2 (continued)

	FY 1978 Est.	FY 1979 Budget
Advanced isotope separation	$ 52.1	$ 54.2
Nuclear energy assessments	15.6	6.3
Alternative advanced reactors	---	20.0
Light water reactor facilities	28.1	10.0
International spent fuel storage	5.0	3.0
Hydroelectric	19.0	8.0
Biomass	20.7	26.9
Basic energy sciences	(177.4)	(211.5)
Nuclear sciences	27.1	29.7
Materials sciences	76.1	94.3
Chemical sciences	56.6	57.8
Engineering, mathematics, & geosciences	12.4	24.0
Advanced energy projects	3.2	4.0
Other	2.0	1.7
Advanced technology & assessments	7.5	21.0
TOTAL, Energy Supply - R&TD	$2,743	$2,670
2. Energy Supply - PD&D		
Solar heating & cooling demonstration	$ 65.8	$ 36.0
TOTAL, R&D in Energy Supply - PD&D	$ 66	$ 36
3. Conservation		
Electric energy systems	$ 40.3	$ 40.0
Buildings & community systems	55.2	59.0
Industrial conservation	29.3	48.5
Transportation	65.0	97.5
Energy storage systems	50.2	58.0
Improved conversion	58.8	78.0
Inventors program support	---	2.0
Appropriate technology	3.0	3.0
TOTAL, R&D in Conservation	$ 302	$ 386
4. Environment (all R&D)		
Overview & assessment	$ 51.4	$ 51.1
Biomedical & environmental research	166.4	157.5
TOTAL, Environmental R&D	$ 218	$ 209

Table B-2 (continued)

	FY 1978 Est.	FY 1979 Budget
5. Basic Sciences (all R&D)		
Life sciences research & biomedical applications	$ 42.5	$ 40.8
High energy physics	274.2	294.7
Nuclear physics	80.4	90.8
TOTAL, Basic Sciences	$ 397	$ 426
6. Atomic Energy Defense Activities		
Inertial confinement fusion	$ 129.6	$ 126.0
Naval reactor development	247.4	290.6
Weapons R&D & testing	679.1	718.1
Security & safeguards	40.7	43.1
Intelligence & arms control	24.7	28.4
TOTAL, R&D in Atomic Energy Defense Activities	$1,122	$1,206
TOTAL, DOE R&D above	$4,848	$4,933

Source: Agency budget justification.
[1]Amount included in the FY 1978 supplemental appropriation.

Table B-3. National Aeronautics and Space Administration Budget Summary (in thousands)

	Budget Plan		
	FY 1977	FY 1978	FY 1979
Research and Development			
Space Transportation Systems	$1,763,700	$1,751,500	$1,827,700
Space shuttle	1,413,100	1,349,200	1,439,300
Space flight operations	199,200	267,800	311,900
Expendable launch vehicles	151,400	134,500	76,500
Space Science Programs	$ 380,325	$ 404,700	$ 513,200
Physics and astronomy	166,300	224,200	285,500
Lunar and planetary exploration	191,900	147,200	187,100
Life sciences	22,125	33,300	40,600
Space and Terrestrial Applications	$ 206,300	$ 243,900	$ 283,400
Space applications	198,200	234,800	274,300
Technology utilization	8,100	9,100	9,100
Aeronautics and Space Technology Programs	$ 278,100	$ 333,200	$ 375,400
Aeronautical research and technology	190,100	228,000	264,100
Space research and technology	82,000	97,700	108,300
Energy technology applications	6,000	7,500	3,000
Tracking and Data Acquisition	$ 255,000	$ 278,300	$ 305,400
TOTAL RESEARCH AND DEVELOPMENT	$2,883,425	$3,011,600	$3,305,100
Construction of Facilities	$ 118,090	$ 162,340	$ 152,500
Research and Program Management	$ 844,361	$ 890,200	$ 914,000
TOTAL, Budget Plan	$3,845,876	$4,064,140	$4,371,600
OUTLAYS	$3,845,876	$3,981,600	$4,270,100

Source: Agency budget justification.

Table B-4. National Institutes of Health[1] (Budget Authority in millions)

	FY 1977	FY 1978		FY 1979
	Actual	President's Budget	Congressional Appropriation	Budget
Cancer	$ 794.9	$ 800.8	$ 852.1	$ 858.4
Heart, Lung, & Blood	374.7	383.7	424.3	432.2
Dental	51.4	55.0	57.5	57.8
Arthritis, Metabolism & Digestive Diseases	199.4	205.2	243.5	249.4
Neurological, etc.	148.4	154.9	171.1	173.6
Allergy & Infectious Diseases	132.9	147.0	154.0	159.8
General Medical Sciences	161.1	180.3	184.1	185.0
Child Health & Human Development	135.8	146.6	156.6	191.2
Aging	27.8	32.5	34.9	35.9
Eye	59.4	60.8	80.7	82.4
Environmental Health Sciences	46.9	56.6	58.7	63.9
Research Resources	137.0	101.6	144.5	148.5
Foggarty International Center	8.0	8.4	8.5	8.5
National Library of Medicine	35.2	36.7	37.5	39.8
Office of Director	16.2	17.9	18.9	19.4
TOTAL	$2,329.1	$2,388.0	$2,626.9	$2,705.8

Source: Agency budget justification.
[1]Excludes training and "buildings and facilities."

Table B-5. Alcohol, Drug Abuse, and Mental Health Administration (Research only; Budget Authority in millions)

	FY 1977	FY 1978		FY 1979
	Actual	President's Budget	Congressional Appropriation	Budget
General Mental Health	$106.9	$106.9	$112.0	$135.4
Drug Abuse	34.0	34.0	34.1	45.9
Alcoholism	12.6	13.2	16.2	21.2
TOTAL	$153.5	$154.1	$162.3	$202.5

Source: Agency budget justification.

Table B-6. National Science Foundation[1] (Budget Plan in millions)

	FY 1977	FY 1978		FY 1979
	Actual	Budget Request	Current Plan[2]	Budget
Mathematical Sciences	$ 20.1	$ 21.8	$ 21.5	$ 23.1
Computer Research	15.8	17.0	16.6	18.1
Physics	54.0	59.4	58.8	65.3
Chemistry	40.2	44.3	43.6	47.7
Engineering	41.8	46.1	45.6	49.6
Materials Research	52.6	60.6	59.9	64.5
Astronomical Sciences	52.2	58.0	57.1	60.5
Atmospheric Sciences	49.1	55.9	55.0	59.1
Earth Sciences	29.1	34.8	34.3	38.5
Ocean Sciences	53.2	58.9	58.0	63.3
Arctic Research	4.6	5.8	5.7	5.9
Physiology, Cellular & Molecular Biology	51.3	58.9	57.3	61.3
Behavioral & Neural Sciences	23.8	28.3	28.3	33.1
Environmental Biology	30.2	33.6	32.6	34.2
Social Sciences	21.3	24.0	24.0	29.4
Basic Research Stability Grants	----	----	4.5[3]	----
Antarctic Program Research Support	6.3	6.5	6.5	6.5
	$ 38.9	$ 41.0	$ 41.8	$ 44.2

Table B-6 (continued)

	FY 1977	FY 1978		FY 1979
	Actual	Budget Request	Current Plan[2]	Budget
Applied Science & Research Applications[4]	62.4	76.5	57.9	73.9[5]
Scientific, Technological, & International Affairs	20.7	24.1	24.6	24.3
Science Education R&D	11.1	8.2	8.2	11.7
Science & Society	4.1	5.2	5.4	6.4
Program Development & Management	45.5	47.8	52.0	54.8
TOTAL	$728.3	$816.7	$799.2	$875.4

Source: Agency budget justification.
[1]Excludes Scientific Personnel and Science Education other than R&D.
[2]Current plan is based on actual legislation and deferrals, carryovers and adjustments of prior year budgets.
[3]These funds have been reprogrammed to university-industry cooperative research. See text, Chapter 2, Section C, "R&D in Colleges and Universities."
[4]This program replaces the Research Applied to National Needs (RANN) program.
[5]Includes $6.9 million in FY 1978 funds deferred into FY 1979.

Table B-7. Environmental Protection Agency: "Research and Development" Appropriation (Budget Authority in millions)

	FY 1978 Est.	FY 1979 Budget
Air	$ 42.4	$ 52.7
Water Quality	59.0	48.4
Water Supply	16.1	16.2
Solid Waste	7.7	10.9
Pesticides	12.1	12.0
Radiation	.8	.9
Noise	---	---
Interdisciplinary	23.4	34.8
Toxic Substances	3.6	10.5
Energy	130.6	114.8
Program Management and Support	25.6	23.1
TOTAL	$321.2	$324.1

Source: Agency budget justification.

Table B-8. EPA: Office of Research and Development Budget by Media (Budget Authority in millions)

Media	FY 1978 Est.	FY 1979 Budget
Air	$ 42.4	$ 52.7
Water Quality	56.1	48.4
Water Supply	16.1	16.2
Solid Waste	7.7	10.9
Pesticides	9.6	9.5
Radiation	.8	.9
Interdisciplinary	23.4	34.8
Toxics	3.6	10.5
Energy	130.6	114.8
Program Management and Support	7.2	7.6
TOTAL ORD Program	$297.5	$306.2

Source: EPA, Office of Research and Development budget summary.

Table B-9. EPA: Office of Research and Development Budget by Program Area (Budget Authority in millions)

Program Area	FY 1978 Est.	FY 1979 Budget
Health Effects	$ 52.5	$ 68.6
Ecological Effects	31.0	34.1
Transport and Fate	16.1	24.0
Industrial Processes	18.2	20.0
Public Sector	38.7	28.4
Monitoring and Tech. Support	37.3	51.7
Energy Control	91.6	57.8
Anticipatory	4.7	13.9
Program Management and Support	7.2	7.6
TOTAL ORD Program	$297.5	$306.2

Source: EPA, Office of Research and Development budget summary.

Appendix C

R&D in Industry Supplementary Tables

Table C-1. Industry Spending for R&D by SIC Groupings: 1975 and 1976 (in millions)

Industry	Total R&D Funds		1976 R&D Funds by Source	
	1975	1976	Federal	Company
TOTAL	$24,096	$26,618	$9,195	$17,423
Food & Kindred Products	309	339	•	•
Textile & Apparel	65	71	•	•
Lumber, Wood Products, & Furniture	91	101	0	101
Paper & Allied Products	249	279	•	•
Chemicals & Allied Products	2,731	3,009	266	2,744
Industrial Chemicals	1,200	1,331	249	1,082
Drugs & Medicines	992	1,092	10	1,083
Other Chemicals	539	586	7	579
Petroleum Refining & Extraction	692	766	•	•
Rubber Products	467	499	•	•
Stone, Clay & Glass Products	234	269	•	•
Primary Metals	443	506	27	479
Ferrous Metals & Products	215	254	4	250
Nonferrous Metals & Products	228	252	23	229
Fabricated Metal Products	321	351	36	316
Machinery	3,192	3,493	534	2,959
Office, Computing & Accounting Machines	2,219	2,397	509	1,888

Table C-1 (continued)

Industry cont.	Total R&D Funds		1976 R&D Funds by Source	
	1975	1976	Federal	Company
Electrical Equipment & Communication	5,075	5,623	2,489	3,133
Radio & TV Receiving Equipment	51	52	0	52
Electronic Components	548	684	*	*
Communication Equipment & Communication	2,370	2,519	1,087	1,431
Other Electrical Equipment	2,106	2,368	*	*
Motor Vehicles & Motor Vehicles Equipment	2,333	2,777	329	2,448
Other Transportation Equipment	88	94	46	48
Aircraft & Missiles	5,711	6,114	4,724	1,390
Professional & Scientific Instruments	1,188	1,307	156	1,152
Scientific & Mechanical Measuring Instruments	265	313	10	304
Optical, Surgical, Photographic & Other Instruments	923	994	146	848
Other Manufacturing Industries	202	221	4	217
Nonmanufacturing Industries	705	798	333	465

Source: NSF, data for Research and Development in Industry 1976.
*Not separately available but included in total.

Table C-2. Industry Spending for R&D by Business Week Groupings: 1975 and 1976[1] (in millions)

Industry	1976	% Change from 1975
TOTAL	$16,225	+11.6%
Aerospace	885	+11.0%
Appliances	77	+5.8%
Automotive	2,942	+17.8%
Building Materials	173	+3.4%
Chemicals	1,439	+8.8%
Conglomerates	582	+15.5%
Containers	130	+9.8%
Drugs	1,292	+10.8%
Electrical, Electronics	1,400	+13.1%
Food, Beverages	302	+17.3%
General Machinery	338	+12.3%
Instruments	828	+11.8%
Leisure Time	118	+43.6%
Metals & Mining	157	+4.3%
Miscellaneous Manufacturing	521	+16.3%
Natural Resources	753	+7.5%
Office Equipment, Computers	1,978	+7.8%
Oil Service & Supply	133	+19.5%
Paper	112	+9.3%
Personal Care Products	274	+11.6%
Service Industries	96	+16.4%
Special Machinery	445	+12.4%
Steel	124	+20.3%
Telecommunications	775	+5.5%
Textiles, Apparel	24	+11.2%
Tires & Rubber	307	-3.2%
Tobacco	19	+2.0%

Source: "What 600 Companies Spend for Research" (Business Week, June 27, 1977, Copyright 1977 by McGraw-Hill Inc.).

[1]Based on SEC data for the 600 companies that reported R&D as a separate item and have sales of at least $35 million and R&D expenditures of $1 million or more.

Table C-3. Applied Research and Development Performed by Industry, by Product Field and Source of Funds: 1975[1] (in millions)

	Total	Federal	Company
TOTAL	$22,837	$8,611	$14,226
Guided missiles & spacecraft	2,918	2,559	359
Food & kindred products	292	1	291
Chemicals, except drugs & medicines	1,703	23	1,680
Drugs & medicines	760	11	749
Petroleum refining & extraction	412	7	405
Rubber & miscellaneous plastics	349	e	347
Stone, clay, & glass products	164	e	163
Primary metals	302	10	292
Fabricated metal products	e	473	498
Machinery	3,730	200	2,530
Office, computing, & accounting machines	(1,412)	(125)	(1,287)
Electrical equipment, except communication	887	189	698
Communication equipment & electronic components	3,976	1,977	1,999
Motor vehicles & other transportation equipment	e	e	e
Aircraft & parts	2,292	1,593	699
Professional & scientific instruments	e	299	824
Other product fields, not elsewhere classified	2,017	1,050	964

Source: Research and Development in Industry 1975 (NSF 77-324).
*Not separately available but included in total.
eStatistically valid amount not separately available.
[1]These 1975 data have not yet been revised. Therefore, the totals do not agree with those in Table 24.

Table C-4. Basic Research Performed by Industry, by Field of Science[1] (in millions)

	1973	1974	1975
TOTAL	$621	$677	$702
Physical sciences	273	315	316
Chemistry	(192)	(227)	(231)
Mathematics	14	13	12
Environmental sciences	7	11	11
Engineering (including metallurgy)	182	175	192
Life sciences	100	117	129
Biological sciences	(75)	(81)	(90)
Clinical medical sciences	(25)	(36)	(38)
Other	46	45	41

Source: Research and Development in Industry 1975 (NSF 77-324).
[1]These data have not yet been revised. Therefore, the 1975 total does not agree with that in Table 24.

List of References

Citations to all publications referred to in this book will be found in one of three categories below. The "General" section contains publications pertaining to R&D in the federal budget; the "Agency Budgets" lists the congressional budget justifications of the individual agencies, and the third section, "R&D, Industry, and the Economy," contains the documents related to Part II of the book in two subsections, "R&D in Industry" and "R&D and the Economy."

A. General

Blanpied, William A., and Lighthizer, Catherine, eds.; *Research and Development in the Federal Budget: Colloquium Proceedings, June 15–16, 1976* (Washington, D.C.: AAAS, 1976).

Carey, William D.; "A Policy Oriented R&D Budget" (*Science*, February 17, 1978).

Economic Report of the President Together with the Annual Report of the Council of Economic Advisers: Transmitted to the Congress January 1978 (Washington, D.C.: Government Printing Office, 1978).

Federal Grant and Cooperative Agreement Act of 1977, Public Law 95–224 (Washington, D.C.: Government Printing Office, 1977).

National Academy of Sciences; *Fundamental Research and the Process of Education* (Committee on Fundamental Research Relevant to Education, Washington, D.C.: NAS, 1977).

——; *The Federal Investment in Knowledge of Social Problems* (Final report of the Study Project on Social R&D, Washington, D.C.: NAS, 1978). *See also:* Abramson, Mark A., *The Funding of Social Knowledge Production and Application: A Survey of Federal Agencies* (Companion volume [No. 1] to the final report of the Study Project on Social R&D, Washington, D.C.: NAS, 1978).

National Science Foundation; *Federal Funds for Research, Development, and Other Scientific Activities: Fiscal Years 1976, 1977, and 1978, Vol. XXVI, Detailed Statistical Tables, Appendices C and D;* Surveys of Science Resources Series, NSF 77–317 (Washington, D.C.: NSF, July 1977).

——; *National Patterns of R&D Resources: Funds and Manpower in the United States, 1953–1977;* Surveys of Science Resources Series, NSF 77–310 (Washington, D.C.: Government Printing Office, 1977).

——; *National Patterns of R&D Resources: Funds and Manpower in the United States, 1953–1978-79* (in press).

National Science and Technology Policy, Organization, and Priorities Act of 1976, Public Law 94-282 (Washington, D.C.: Government Printing Office, 1976).

Office of Management and Budget; *The Budget of the United States Government: Fiscal Year 1979* (Washington, D.C.: Government Printing Office, 1978; cited as *The Budget* in text).

——; "Budget Message of the President," in *The Budget of the United States Government: Fiscal Year 1979* (Washington, D.C.: Government Printing Office, 1978).

——; *The Budget of the United States Government: Fiscal Year 1978* (Washington, D.C.: Government Printing Office, 1977).

——; *The Budget of the United States Government: Fiscal Year 1979; Appendix* (Washington, D.C.: Government Printing Office, 1978).

——; *The Budget of the United States Government: Fiscal Year 1978; Appendix* (Washington, D.C.: Government Printing Office, 1977).

——; *Data for Special Analysis P: Fiscal Year 1979* (Washington, D.C.: OMB, January 1978).

——; *Data for Special Analysis P: Fiscal Year 1978* (Washington, D.C.: OMB, January 1977).

——; *Special Analyses: Budget of the United States Government: Fiscal Year 1979* (Washington, D.C.: Government Printing Office, 1978).

——; *Special Analyses: Budget of the United States Government: Fiscal Year 1978* (Washington, D.C.: Government Printing Office, 1977).

Office of Science and Technology Policy; *Proposed Remarks by Frank Press at the IBM Interdivisional Symposium* (Washington, D.C.: OSTP, December 7, 1977).

——; *Testimony by Frank Press before the Subcommittee on Science, Technology, and Space, Committee on Commerce, Science, and Transportation, United States Senate* (Washington, D.C.: OSTP, February 10, 1978).

Office of the White House Press Secretary; *Remarks of the President at Medal of Science Awards* (Washington, D.C., November 22, 1977).

——; *State of the Union Message* (Washington, D.C., January 19, 1978).

Phillips, Don I., Cleare, Catherine C. and Patterson, Maria, eds.; *Research and Development in the Federal Budget: Colloquium Proceedings, June 15–16, 1977* (Washington, D.C.: AAAS, 1977).

Shapley, Willis H.; *Research and Development in the Federal Budget: FY 1977* (Washington, D.C.: AAAS, 1976; cited as AAAS-I in text).

Shapley, Willis H., Phillips, Don I., and Roback, Herbert; *Research and Development in the Federal Budget: FY 1978* (Washington, D.C.: AAAS, 1977; cited as AAAS-II in text).

B. Agency Budgets*

Agency for International Development; *Congressional Presentation* (Washington, D.C., 1978).

Alcohol, Drug Abuse, and Mental Health Administration; *Justification of Appropriation Estimates for Committee on Appropriations* (Washington, D.C., 1978).

Department of Agriculture; *1979 Budget Explanatory Notes*, Vol. 1 (Washington, D.C., 1978).

Department of Defense; *Program for Research, Development, and Acquisition: FY 1979* (Statement by The Honorable William J. Perry, Under Secretary of Defense, Research, and Engineering, to the Congress of the United States, 95th Congress, Second Session, February 1, 1978).

Department of Energy; *Congressional Budget Request: FY 1979*, Vols. 1–5 (Washington, D.C., 1978).

——; *FY 1979 Budget to Congress: Budget Highlights* (Washington, D.C., 1978).

Environmental Protection Agency; *Justification of Appropriation Estimates for Committee on Appropriations, Fiscal Year 1979* (Washington, D.C., 1978).

——; *Office of Research and Development: Budget Summary, FY 1979* (Washington, D.C., 1978).

National Aeronautics and Space Administration; *Budget Estimates: Fiscal Year 1979*, Vols. 1–3 (Washington, D.C., 1978).

National Institutes of Health; *Justification of Appropriation Estimates for Committee on Appropriations* (Washington, D.C., 1978).

National Science Foundation; *FY 1979 Budget Estimate to the Congress* (Washington, D.C., 1978).

Office of Science and Technology Policy; *United States Climate Program: Fiscal Year 1979* (Washington, D.C., January 1978).

C. R&D Industry, and the Economy

1. R&D in Industry

Battelle Memorial Institute; *Probable Levels of R&D Expenditures in 1978: Forecast and Analysis* (Columbus, Ohio: Columbus Laboratories, 1977).

"C&EN's Facts and Figures for the Chemical Industry" (*Chemical and Engineering News*, June 6, 1977).

"Chemical Firms' R&D Support up 8% in 1978" (*Chemical and Engineering News*, January 16, 1978).

"Dupont Shifts R&D Toward Established Lines" (*Chemical and Engineering News*, October 3, 1977).

"$45.2 Billion for R and D" (*Research/Development*, January 1978).

Industrial Research Institute; *Research-on-Research* (New York, New York, November 1976).

McGraw-Hill Publications Company; *20th Annual McGraw-Hill Survey: Business' Plans for Research and Development Expenditures, 1975–78* (New York: McGraw-Hill Economics Department, May 9, 1975).

——; *21st Annual McGraw-Hill Survey: Business' Plans for Research and Development Expenditures, 1976–79* (New York: McGraw-Hill Economics Department, May 21, 1976).

---

* Agency congressional budget justifications are generally published in substantial part or in full in the "Hearings" of the legislative (authorization) and appropriations committees having jurisdiction.

——; *22nd Annual McGraw-Hill Survey: Business' Plans for Research and Development Expenditures, 1977–80* (New York: McGraw-Hill Economics Department, May 20, 1977).

National Science Foundation; *Research and Development in Industry 1974: Funds, 1974; Scientists and Engineers, January 1975*, Surveys of Science Resources Series, NSF 76-322 (Washington, D.C.: Government Printing Office, September 1976).

——; *Research and Development in Industry 1975: Funds, 1975; Scientists and Engineers*, January 1976, Surveys of Science Resources Series, NSF 77-324 (Washington, D.C.: Government Printing Office, November 1977).

Pharmaceutical Manufacturers Association; *Annual Survey Report: Ethical Pharmaceutical Industry Operations 1976–1977* (Washington, D.C.: PMA, December 1977).

——; *Annual Survey Report: Medical Device and Diagnostic Product Operations: 1973–1975 with Forecasts for 1976* (Washington, D.C.: PMA, June 1977).

"R&D Funding Will Increase in Real Dollars this Year" (*Industrial Research*, January 1978).

Schweitzer, Glenn E.; *Regulation and Innovation: The Case of Environmental Chemicals* (Program on Science, Technology, and Society, Cornell University, February 1978).

"What 600 Companies Spend for Research" (*Business Week*, June 27, 1977).

2. *R&D and the Economy*

Department of Commerce, *The Role of New Technical Enterprises in the U.S. Economy* (A Report of the Commerce Technical Advisory Board to the Secretary of Commerce, Washington, D.C., January 1976).

——; *Statement of Jordan J. Baruch before the Subcommittee on Science, Technology and Space of the Committee on Commerce, Science, and Transportation, U.S. Senate, and before the Subcommittee on Science, Research, and Technology of the Committee on Science and Technology, U.S. House of Representatives, on U.S. Science and Technology* (Washington, D.C., February 14, 1978).

——; *U.S. Technology Policy: A Draft Study*, Betsy Ancker-Johnson and David B. Chang, Office of the Assistant Secretary for Science and Technology NTIS: PB-263 806 (Washington, D.C.: National Technical Information Service, March 1977).

Freeman, C., "Economics of Research and Development," in *Science, Technology and Society: A Cross-Disciplinary Perspective*, Ina Spiegel-Rösing and Derek de Solla Price, eds. (London and Beverly Hills, Cal., Sage Publications, 1977).

Gold, Bella; *Advancing the Technological Capabilities of U.S. Industries: Needs and Suggested Policies* (Statement to the Joint Hearing of the Senate Subcommittee on Science, Technology and Space and the House Subcommittee on Science, Research, and Technology; Washington, D.C., February 14, 1978).

Hannay, N.D.; *Technological Innovations and National Priorities* (Bell Laboratories, Murray Hill, N.J., January 10, 1978).

National Academy of Sciences/National Academy of Engineering; *Technology, Trade and the U.S. Economy* (Report of a Workshop held at Woods Hole, Massachusetts, August 22–31, 1976; Washington, D.C.: NAS, 1978).

National Science Foundation; *Proposed Remarks by Richard C. Atkinson to the Medals Awards Ceremonies of the Franklin Institute* (Washington, D.C.: NSF, November 2, 1977).

——; *Relationships Between R&D and Economic Growth/Productivity, Papers and Proceedings of a Colloquium* (in press).

——; *Research and Development and Economic Growth/Productivity, Papers and Proceedings of a Colloquium* (Washington, D.C.: Government Printing Office, 1972).

——; *Science Indicators 1976* (Report of the National Science Board, Washington, D.C.: NSF, 1977).

Ruttenberg, Stanley H.; *Statement at a Joint Hearing of the Senate Subcommittee on Science, Technology and Space and the House Subcommittee on Science, Research and Technology* (Washington, D.C., February 14, 1978).

About the Authors

Willis H. Shapley was educated at Harvard College and the University of Chicago, where he was a graduate fellow and research assistant in political science. He entered government service in 1942 with the Bureau of the Budget, Executive Office of the President, where for 23 years he specialized in research and development, national defense, and space programs, becoming in the 1960s, Deputy Chief of the Military Division and Special Assistant to the Director for Space Program Coordination.

In 1965, Mr. Shapley became Associate Deputy Administrator at NASA, in which position he served for 10 years as the principal senior assistant to the Administrator and Deputy Administrator of NASA. Since retiring from his NASA position in September 1975, Mr. Shapley has served as a consultant to the Administrator of NASA, the Office of Management and Budget, the Office of Science and Technology Policy, and other organizations. As a consultant to the American Association for the Advancement of Science, he has been the principal author of the first three annual AAAS reports on R&D: *Research and Development in the Federal Budget: FY 1977; Research and Development in the Federal Budget: FY 1978;* and the present volume. Mr. Shapley has received the Rockefeller Public Service Award, NASA's Distinguished Service Medal, and the Career Service Award of the National Civil Service League.

Don I. Phillips is a Public Policy Program Manager in the Office of Public Sector Programs at the American Association for the Advancement of Science. He has assisted Mr. Shapley in the preparation of *Research and Development in the Federal Budget: FY 1978*, prepared the proceedings of the 1977 AAAS colloquium on research and development, and contributed to other R&D and science policy activities of the office. His prior experience includes science curriculum development and administration at AAAS, research and development administration at the University of Maryland, and policy development and analysis as an Education Policy Fellow at the National Institute of Education. Dr. Phillips received the B.S. and Ph.D. degrees in chemistry from the University of Michigan and Harvard University, respectively. He was also a postdoctoral research fellow at Harvard.

Additional Titles in this Series

Research and Development in the Federal Budget: FY 1977

Volume I in the R&D series provides current and authoritative coverage of R&D in the federal budgeting process. Topics included for discussion in this volume are decision-making on federal funds for research and development; changes being implemented in the congressional budget process and how they affect future R&D budgets; and how the 1977 federal budget was prepared.

Research and Development in the Federal Budget: FY 1978

Volume II in this series offers a timely, analytic summary and interpretive report on R&D in the 1978 federal budget and a stimulating discussion of significant, current, and basic issues. These topics include FY 1977 budget outcome; FY 1978 budget analysis; future R&D budget outlook; congressional role in R&D budgeting; and how R&D budget decisions should be made.

Research and Development in the Federal Budget: Colloquium Proceedings 1976

The 1976 Colloquium on Research and Development in the Federal Budget (June 15–16) provided a forum for exploring several of the long-range and recurring issues identified in the publication *R&D in the Federal Budget: FY 1976*.

Research and Development in the Federal Budget: Colloquium Proceedings 1977

The 1977 Colloquium on Research and Development in the Federal Budget (June 15–16) brought leaders of the scientific and technological communities together with responsible decision-makers in the Executive and Legislative Branches of government to discuss problems of R&D budgets and the budget process as it affects R&D.

American Association for the Advancement of Science

Founded in 1848, AAAS is the world's leading general scientific society with about 120,000 individual members interested in the advancement of science, in improving the effectiveness of science in promoting human welfare, and in increasing the public understanding and appreciation of science. Through its nearly 300 affiliated societies and academies covering the entire spectrum of science and technology, AAAS has a significant relationship with about 2 million individuals directly involved in science and technology. This relationship together with the broad scope of its members' interests has uniquely equipped AAAS to exercise a leadership position in convening expert bodies at annual meetings and in committee to analyze the technological, social, and political aspects of significant problems facing our society.

American Association for the Advancement of Science, 1515 Massachusetts Ave., NW, Washington, D.C. 20005